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# *POLICIES AND PROCEDURES FOR FREE-FLOWING GROUNDWATER MANAGEMENT IN EGYPT'S WESTERN DESERT*

## *Report No. 16*
### *Main Document*

**June 1999**

**Water Policy Program**
**International Resources Group    Winrock International    Nile Consultants**

**Task Order No. 807**
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# POLICIES AND PROCEDURES FOR FREE-FLOWING GROUNDWATER MANAGEMENT IN EGYPT'S WESTERN DESERT

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June 1999

For
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| | |
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| DRPTC | Development Research and Technological Planning Center, Cairo University |
| GARPAD | General Authority for Rehabilitation Projects and Agricultural Development |
| GDDO | General Desert Development Organization |
| GOE | Government of Egypt |
| MALR | Ministry of Agriculture and Land Reclamation |
| MHNC | Ministry of Housing and New Communities |
| MPWWR | Ministry of Public Works and Water Resources |
| NVAD | New Valley Agricultural Department |
| NVDA | New Valley Development Authority |
| NVWRDD | New Valley Water Resources Development Department |
| NWRC | National Water Resources Center |
| PBDAC | Principal Bank for Development and Agriculture Credit |
| WUU | Water User Union |
| WUUs | Water User Unions |

## EXECUTIVE SUMMARY

### Introduction

The purpose of this report is to present the results of the work carried out in completion of Benchmark C.2 of the Memorandum of Understanding between the Government of the Arab Republic of Egypt (GOE) and USAID/Egypt for the Agricultural Policy Reform Program (APRP) Tranche III (FY 98/99). The benchmark states:

> *The GOE (MPWWR) will adopt policies and procedures for reducing water loss and land degradation due to improper operation and management of free-flowing groundwater in the reclaimed areas of the Western Desert.*

This document presents an improved policy framework to ensure appropriate management of the Nubia Sandstone Aquifer and its free-flowing wells. Implementation of this policy is expected to lead to the following:

- Better utilization, management and conservation of groundwater resources in the Western Desert development areas where free-flowing groundwater conditions prevail, which, in turn, will lead to water savings, improved agriculture conditions in 75,000 feddans of old and newly reclaimed area, and more sustainable agriculture production.
- Saving 0.3 bcm of water per year.
- Mitigation of adverse environmental effects such as water logging, drainage problems, and soil salinization, which have resulted in serious negative impacts on agricultural production in the Oases.
- Sustaining the economic life of the Nubia Sandstone Aquifer system.
- Transfer of responsibility for well drilling, operation, and maintenance and groundwater management from the MPWWR to local stakeholder management organizations, with continuing control and technical support from the Ministry.
- Development of a policy model that can be extended to other groundwater areas.

### Background

The non-renewable groundwater of the Nubia Sandstone Aquifer is the only source of water in the Western Desert of Egypt. Studies indicate that the deep groundwater from the Nubia Sandstone Aquifer can be extracted in the Western Desert at a rate of 2.4 bcm per year over a period of 100 years. Much of this aquifer is under artesian pressure. Deep wells in some reclaimed areas (200 m in Siwa and 800 to 1,000 m in El-Farafra and El-Dakhla) are free-flowing at relatively high rates (5,000 to 30,000 $m^3$ per day) and high pressures (5 to 8 atmospheres at the wellheads). In these areas a total of 1,636 uncontrolled, continuously flowing wells produce at an annual rate of 0.675 bcm. Control of the flow from these wells is difficult, due to problems associated with sudden backpressure in the water-bearing formation if the well is subjected to rapid and frequent shut-down. Since water users practice irrigation only during the daylight hours, almost half of this water is wasted. Further, the unused flows cause negative environmental effects such as water logging, drainage problems, and soil salinization, resulting in serious impacts on agricultural production in the Oases.

**Accomplishments**

Reduced water wastage and extended life of the free-flowing groundwater resource from the Nubia Sandstone Aquifer of Egypt's Western Desert will result from implementation of the recommended policies.

Benchmark C.2 and its two verification indicators have been achieved. These two verification indicators are:

1. MPWWR will approve a policy package for free-flowing groundwater in reclaimed areas.
2. Initiate the formation of a groundwater user association in a selected reclaimed area in the Western Desert.

The first indicator was achieved with preparation of this report and the recommended policy package contained herein for which approval is expected following the workshop held on June 11-12, 1999.

The second indicator was achieved on May 13, 1999, when formal certificates were presented to officers of three new Water User Unions formed in the West Qasr El-Farafra area. These are the first ever WUUs formed in the Western Desert in accordance with Law #213.

**Recommended Policies**

1. Free-flowing well discharge will be adjusted monthly to match crop irrigation requirements within the command area of each particular well, with the maximum discharge not exceeding the well's design future pumping rate.
2. For free-flowing wells, nighttime well flow will be stored on the land surface, either in the existing canals or new storage facilities, and daytime well flow will be controlled.
3. The MPWWR will establish a program of continuous groundwater monitoring for all wells (private and public).
4. Operating criteria will be defined for transition from free-flowing to pumped conditions of the wells.
5. The MPWWR will continue the program for establishment of water user organizations in accordance with Law #213.
6. No growth of unofficial irrigation will be allowed.
7. A working group will be established with membership from MPWWR, MALR, and MHNC, chaired by the representative of MPWWR, to provide continuing review of issues/conditions and policies for managing the groundwater resources in the Western Desert.

Recommended Procedures

A. Before the beginning of each growing season, the WUU for each well (or wells) will provide to the NVWRDD the total areas of each crop to be grown that season.

B. Personnel of the NVWRDD will determine the water delivery schedule for each month of each season and provide results to the leader of the WUU.

C. With storage of nighttime flow, the free-flowing well discharge rate will be set by NVWRDD personnel to deliver (in 24 hours) the volume of water needed for each day's irrigation. The well discharge will be changed only once each month as per policy #1.

D. Close contacts and coordination between the MPWWR(NVWRDD), MALR(NVAD), and WUUs will be needed to solve irrigation problems and to develop the water delivery schedule each season.

E. Groundwater extraction zones of future wells will be distributed among different depth zones of the aquifer over the reclaimed area.

F. The MPWWR, through the RIGW, will conduct a research and demonstration study of the use of remotely actuated automatic slow-closing valves for flow regulation (and/or possible future nighttime closure) of the free-flowing wells.

G. A periodic maintenance program for all irrigation water facilities will be established to provide compatible utilization, conservation, and preservation of the groundwater resources over the planned period of groundwater mining in the Western Desert.

H. The MPWWR and MALR will jointly conduct a review of contract compliance within the well command areas to determine if contract stipulations have been met by the landholders pursuant to Law #143 of 1981. If violations exist that will make these lands available to new farmers, the lands should be reallocated to ensure that all land within the command area is fully utilized.

I. The NVWRDD needs to be strengthened and adequately budgeted for the number of trained technical personnel in each required specialization and for the equipment and measuring devices necessary for performing its roles and responsibilities.

J. The MPWWR, through the Water Communication Unit, will establish an ongoing educational program, for all stakeholders and the public, on water resource issues affecting free-flowing groundwater management in the Western Desert.

**Discussion and Justification**

In the following, the numbers correspond to those of the foregoing list of recommended policies. An expanded discussion and justification of these policies and associated procedures is given in the body of the report, especially in Section 4.4 and Section 5.

1. By implementing policy #1 together with any policy that prevents loss of nighttime flows, the free-flowing well discharge (total daytime and nighttime flows) will be matched to the crop irrigation requirements within the command areas, and water in excess of irrigation needs will no longer be released to the drains. In this way, the considerable amount of water saved compared to the current practice of constant well discharge will be left in the aquifer for later withdrawal. Limiting the maximum free-flowing well discharge to its design future pumping rate will provide adequate supply of water to the command area over the planned period of groundwater extraction. Exceeding this design rate during free-flow conditions will accelerate the decline of aquifer piezometric levels and hasten the need to begin pumping.

**It must be understood by all concerned with adoption and implementation of policy #1 that restricting the maximum free-flowing well discharge to the design future pumping rate places the same constraints on crop selection during the free-flowing**

**period as during the future pumping period. Thus, there will be no major adjustment of irrigated area as the change from free-flowing to pumped wells occurs. Farmers are free to choose their crops consistent with available irrigation water supply. Both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply. The personnel needs of the NVWRDD will increase due to the need to adequately assess the crop water needs, to be supplied by each well depending on the particular crop mix for each irrigation season, in the area served by the well. An accurate survey of areas planted to each crop for each irrigation season will be needed for each well command area.**

2. Currently, unused nighttime well flow is discharged directly or indirectly to the drains. With implementation of policy #2, the considerable amount of water saved will be left in the aquifer for later withdrawal, thus prolonging the free-flowing condition of the wells and delaying the need to add pumps to the wells. Both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply. There will be little impact on personnel needs of the NVWRDD to operate the system using nighttime storage of well flow. If the nighttime well flow is stored in the existing canals, it will be used directly from the canals together with the daytime well flow. If the nighttime well flow is stored in new storage facilities, the release of stored nighttime water can be handled by the WUU in cooperation with the NVWRDD. In all GARPAD-designed reclaimed areas, the canals are designed and constructed with extra capacity to handle the nighttime well flows. In other areas, new storage facilities may have to be designed and constructed.

3. Policy #3 is needed to provide a complete and continuous base of reliable data for managing the groundwater resources for which the Ministry has responsibility. In the future, such an historical database will allow assessment of the success of any policy changes implemented. Results can be used to determine the necessity of any future corrections to policy. The database is needed whenever groundwater models are used as management tools. In areas allocated for large scale private sector irrigated agriculture projects, the private sector will be required to establish monitoring well networks in accordance with the MPWWR technical guidelines. MPWWR staff must be allowed to periodically monitor these wells to get the required data.

4. Defining the criteria of policy #4 could be a task of the working group (policy #7). Groundwater extraction in areas where free-flowing wells prevail will eventually require pumping. The long-term groundwater utilization plans in these areas should be based upon future pumping conditions even though the wells are currently free-flowing. Such an approach will provide for stable water supply for irrigation within the command area over the entire life of the groundwater production.

   It must be clearly understood by all concerned that in order to sustain the agriculture of the reclaimed areas, the need for pumping of previously free-flowing wells will occur before the free-flowing condition actually ceases. It might be feasible to use surface centrifugal pumps during the transition (*e.g.*, when the daily free-flowing discharge drops below the daily design pumping rate) until the lift for which these pumps are capable of bringing the water to the land surface is exceeded. At that time, submersible or deep well turbine pumps will be needed. When to install these pumps becomes largely a decision based upon economic analysis and should be the responsibility of the MPWWR. This decision should then be communicated to the proper water user organization. When the free-flowing well discharge has declined below water demands, it is probably more economical to pump the well than to replace it with a deeper well that will be free-flowing.

5. The program of formation of water user organizations started in West Qasr El-Farafra should be continued throughout the reclaimed areas of the Western Desert oases. These organizations can play a significant role in ensuring success of the policies for control of free-flowing well discharge to prevent water wastage. Their anticipated role in providing seasonal information on cropping patterns planned by farmers is an essential part of implementation of the recommended policies.
6. Policy #6 will minimize future problems associated with the decreasing quantity and quality of drainage water from the command area that is inherent in any policy of prevention of water wastage and more efficient use of irrigation water. Significant unofficial irrigation, pumping water from the drains to irrigate lands outside the command area, has developed around the reclaimed areas. If the areas of unofficial irrigation are allowed to continue to grow, more people will suffer from inadequate irrigation water supply when the water in the drains becomes less suitable (or even unsuitable) for irrigation.
7. Several issues/conditions and policies for managing the groundwater resources in the Western Desert will need continuing attention. Two examples are: (a) transition from free-flowing to pumped wells (See policy #4) and (b) unofficial irrigation that currently exists on about 10,000 feddans in El-Farafra – Abou-Minqar. Such issues/conditions and policies may best be handled by a working group of representatives of all ministries involved.

# 1 INTRODUCTION

## 1.1 Authorization

The Agricultural Policy Reform Program (APRP) is a four-year United States Agency for International Development (USAID) grant program involving several ministries. The Ministry of Public Works and Water Resources (MPWWR) is the primary Egyptian governmental agency charged with the management of water resources. MPWWR and USAID, under the umbrella of the APRP, jointly designed a water policy package, which consists of integrated water policy and institutional reforms. USAID supports the Ministry's efforts through annual cash transfers based on performance in achieving identified and agreed-upon policy reform benchmarks and technical assistance.

Co-ordination among MPWWR, USAID and the water policy technical assistance program is through the Water Policy Advisory Unit (WPAU) and a project steering committee established by the MPWWR.

Technical assistance for the water policy analysis activity is provided through a water resources results package task order (Contract PCE-I-00-96-00002-00, Task Order 807) under the Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ) between USAID and a consortium headed by the International Resources Group (IRG) and Winrock International. Local technical assistance and administrative support for EPIQ is provided through a subcontract with Nile Consultants.

The EPIQ Water Policy team assists MPWWR to identify and carry out policy reform which will increase the global efficiency and productivity of Egypt's Nile water system under a water resources results package task order. EPIQ directly assists and takes a lead in identifying and achieving annual policy reform benchmarks, working closely with the MPWWR steering committee, WPAU, key ministry officials, and other APRP units.

## 1.2 Purpose of the Report

A Memorandum of Understanding between the Arab Republic of Egypt and USAID listing mutually agreed policy reform benchmarks for the APRP Tranche III period (1 July 1998 – 30 June 1999) was signed on 27 September 1998. Benchmark C.2 states:

> *The GOE (MPWWR) will adopt policies and procedures for reducing water loss and land degradation due to improper operation and management of free-flowing groundwater in the reclaimed areas of the Western Desert.*

Satisfactory achievement of the benchmark requires the accomplishment of two verification indicators:

1. MPWWR will approve a policy package for free flowing groundwater in reclaimed areas.
2. Initiate the formation of a groundwater user association in a selected reclaimed area in the Western Desert.

The purpose of this report is to describe the activities carried out to achieve the benchmark and its verification indicators. An improved policy framework has been prepared to ensure appropriate management of the aquifer and its free-flowing wells. The report also presents documentation on the formation of a groundwater user association in a selected reclaimed area in the Western Desert.

### 1.3 Background

The non-renewable groundwater of the Nubia Sandstone Aquifer is the only source of water in the Western Desert of Egypt, where agriculture and mining development activities are practiced. The Nubia Sandstone Aquifer System is one of the major aquifer systems in northeast Africa, having a huge storage capacity of about 200,000 bcm of fresh water. However, only a small fraction (about 2% or 4,000 bcm) of this can be extracted in the Western Desert.

During the last four decades, important contributions to the understanding of the regional hydrogeologic conditions of the deep aquifer systems in the Western Desert were made, with a special emphasis on the Nubia Sandstone Aquifer and its groundwater potential. These studies were carried out by the Ministry of Agriculture and Land Reclamation, the Ministry of Development and New Communities, the Ministry of Petroleum, and the Ministry of Public Works and Water Resources. A comprehensive report on the hydrogeology of the deep aquifers in the Western Desert and the Sinai has been prepared by the EPIQ Water Policy Team[1].

The results from the studies indicate that the deep groundwater from the Nubia Sandstone Aquifer can be extracted in the Western Desert at a rate of 2.4 bcm per year over a period of 100 years. Previous studies focused primarily on the hydrogeologic characteristics of the deep Nubia Sandstone Aquifer, its groundwater potential, and proposed groundwater development plans. None of the studies sufficiently addressed the policies and procedures required to properly utilize and manage the deep groundwater resources in the Western Desert development areas where conditions producing free-flowing wells prevail.

The development and utilization of groundwater resources in the Western Desert Oases started some centuries ago, but large-scale development was initiated in the early sixties. The current annual groundwater abstraction in the Western Desert is about 0.7 bcm, most of which is being utilized in irrigated agriculture and in the domestic and mining sectors. However, much of this aquifer is under artesian pressure. Deep wells in some reclaimed areas (200 m in Siwa and 800 to 1,000 m in El-Farafra and El-Dakhla) are free-flowing at relatively high rates (5,000 to 30,000 $m^3$ per day) and high pressures (5 to 8 atmospheres at the wellheads). Control of the flow from these wells is difficult, due to problems associated with sudden back pressure in the water-bearing formation if the well is subjected to rapid and frequent shut-down. The back pressure can result in a collapse of the formation around the well and abandonment of the well. While these wells can be controlled on a longer-term cycle (weekly or seasonally, for example), the continuous flow in the shorter-term produces water in excess of demand during the irrigation period, unused flow during the night (the non-irrigation period), and consequent water logging, drainage problems, and soil salinization. These environmental effects may seriously reduce agricultural productivity.

The aquifer is a classic common property, in which an individual well owner can derive no benefit from controlling flows from his or her well, since any water which he or she might

[1] EPIQ, "Report No. 10: Hydrogeology of Deep Aquifers in the Western Desert and Sinai", August 1998.

save will simply be used (or wasted) by another. But because this aquifer is a non-renewable stock resource, the flows may be excessive relative to the optimal rate of exploitation (economic or physical) of the resources. Optimal management requires one of two approaches: individual control of the aquifer (or at least the local well-field) or group regulation (either a local or national organization).

In the areas of El-Dakhla, El-Farafra, and Siwa Oases, a total of 1,636 uncontrolled, continuously flowing wells produce at an annual rate of 0.675 bcm. Since water users practice irrigation only during the daylight hours, almost half of this water is wasted.

The artesian character of the aquifer suggests two phases of use: 1) the free-flowing, or naturally pressurized, stage, which costs little or nothing, other than well investment and maintenance, and 2) the pumping stage, in which the artesian pressure is insufficient and external energy (pumping) must be applied to obtain the water. Proper policy and management would be needed to ensure the optimal length of the first and second phases.

Further, the unused flows cause negative environmental effects such as water logging, drainage problems, and soil salinization, resulting in serious impacts on agricultural production in the Oases.

An improved policy framework needs to be developed to ensure appropriate management of the aquifer and its free-flowing wells. The Government of Egypt needs to adopt a policy package which will provide for reductions in the wasted water and land degradation. Components of the policy package should include:

- A public awareness campaign regarding both the problems inherent in the free-flowing wells and the scarcity of groundwater;
- Provision of economic incentives and aids, such as credit, cost sharing, etc., for structural improvements which can reduce water wastage;
- Enforcement of existing regulations regarding groundwater use; and
- Establishment of groundwater user organizations composed of public and private sector stakeholders, to operate and maintain the well-field and irrigation and drainage system.

Such a policy package will provide for the efficient use of the water resources, reduction of wasted water, reuse of drainage water, and minimization of the environmental damage currently being suffered. A needed future activity in the Western Desert development areas is improvement of on-farm water management.

Implementation of this benchmark is expected to lead to the following:

- Better utilization, management and conservation of groundwater resources in the Western Desert development areas where free-flowing groundwater conditions prevail, which in turn, will lead to water savings, improved agriculture conditions in 75,000 feddans of old and newly reclaimed area, and more sustainable agriculture production.
- Saving 0.3 bcm of water per year.
- Mitigation of adverse environmental effects such as water logging, drainage problems, and soil salinization, which have resulted in serious negative impacts on agricultural production in the Oases.
- Sustaining the economic life of the Nubia Sandstone Aquifer system.

- Transfer of responsibility for well drilling, operation, and maintenance and groundwater management from the MPWWR to local stakeholder management organizations, with continuing control and technical support from the Ministry.
- Development of a policy model that can be extended to other groundwater areas.

### 1.4 Report Organization

This report consists of seven major sections. Section 1 is an introduction highlighting the purpose of the report. Section 2 gives the background and description of the problem causing water wastage and land degradation in the reclaimed areas of the Western Desert, where free-flowing groundwater occurs. Section 3 focuses on the methodology including data and process used in developing the recommended policies and procedures. Section 4 describes a case study in which possible policies and procedures were evaluated using data from the West Qasr El-Farafra reclaimed area. Section 5 gives the resulting policies and procedures that were developed and are recommended for adoption by the MPWWR. Section 6 contains conclusions and recommendations, and Section 7 is a list of references.

# 2 BACKGROUND AND PROBLEM DESCRIPTION

## 2.1 Groundwater Development and Utilization in the Western Desert

### 2.1.1 Overview

Within the context of Egypt's national development goals, the objectives of the regional development of the Western Desert are:

- Settling population away from the overcrowded Nile Valley and Delta.
- Maximizing the use of existing natural resources in the isolated, vast desert areas.
- Connecting these areas to the rest of the country.
- Creating new job opportunities for unemployed youths.

2.1.1.1 Location*:* The Western Desert of Egypt is bounded by the Sudan border on the south, the Mediterranean Sea on the north, the Nile Valley on the east, and the Libyan border on the west. It covers almost 68 percent of the total area of Egypt. It is generally a high plateau interrupted by natural depressions that have land surface elevations at or near sea level. Figure (1) shows the locations of the major depressions and oases El-Kharga, El-Dakhla, El-Farafra, El-Bahariya, Qattara, and Siwa. The oases of El-Kharga, El-Dakhla, El-Farafra, and El-Bahariya, together with intermediate areas (El-Zayat, West Mawhub, and Abu-Minqar) and the southern areas of South Kharga and East Oweinet, are collectively known as the New Valley.

2.1.1.2 Climate of the New Valley*:* The climate of the New Valley in the Western Desert is characterized by hot temperatures and drought. The main meteorological elements are summarized as follows:

<u>Temperature</u>: In summer (April–September), the air temperature generally ranges from 25-37 °C, reaching daily maximums of about 45 °C from time to time during June-September. In winter (October-March), the temperature ranges from 17 to 32 °C, with minimums sometimes dropping to 0 to 5 °C during the night in January-February. There is a significant difference in temperature from day to night, especially in summer, as the day is very hot but the temperature cools rapidly after sunset during both summer and winter.

- <u>Precipitation</u>: There is a notable absence of rainfall throughout the year. The maximum recorded shower during the last twenty years did not exceed 3.5 mm.
- <u>Humidity</u>: The humidity is generally very low from 24-25% and not exceeding 60% in winter.
- <u>Evaporation</u>: Evaporation ranges from 12-26 mm/day during summer and 5-12 mm/day in winter.
- <u>Wind Speed</u>: The wind speed ranges from 1.5 to 5 m/sec. and is characterized by sporadic heavy dusting, especially during the periods April-June and September-October. The results of many studies indicate that wind erosion potential exists during approximately 80% of the year because a wind speed of 1.5 to 3.0 m/sec is able to carry sand particles to a height ranging from 0.1 to 1.6 m. Thus, wind erosion is prevalent and windbreaks are very important for the protection of cultivated areas.

It can be concluded that while the climate is certainly severe, it is favorable for numerous kinds of crops.

2.1.1.3 Hydrogeology and deep aquifer systems*:* The hydrogeological framework of the Western Desert encompasses three principal deep aquifer systems: the lower Miocene Moghra sandy aquifer, the Tertiary/Upper Cretaceous fissured carbonate aquifer; and the Mesozoic/Paleozoic Nubia Sandstone Aquifer. The deep groundwater in these aquifer systems is considered a non-renewable resource, except the part of the Moghra aquifer at the Desert fringes of the Nile Delta region which receives recharge from the adjacent Nile Delta aquifer (EPIQ/WPRP Report #10).

2.1.1.4 Nubia Sandstone Aquifer*:* The Nubia Sandstone Aquifer system in the Western Desert is considered to have the greatest resource development potential. It contains large volumes of fresh groundwater (<1000 ppm) in storage (200,000 bcm). The aquifer development plans should be considered as a mining process with continuous lowering of the aquifer potentiometric levels. The Nubia Sandstone Aquifer transmissivity ranges from 240 $m^2$/d in Toshka basin area to 17,000 $m^2$/d in El-Bahariya Oasis. The potentiometry of the Nubia Sandstone Aquifer indicates a regional NE-N groundwater flow towards the aquifer base level at the Qattara-Siwa-Giaghboub depression, where groundwater is naturally lost at a rate of 90 mcm/year. The groundwater of Nubia Sandstone Aquifer is fresh (<1000 ppm) in the southern and central parts (New Valley) of the Western Desert. But north of $29^0$ N latitude, saline to hyper-saline groundwater saturates the lowermost part of the aquifer. This zone increases in thickness northward toward the Mediterranean Sea.

Groundwater isotope measurements indicate that the groundwater in the Nubia Sandstone Aquifer was formed during several successive humid periods which prevailed over the desert, the last of which was 8,000 years ago. Therefore, the groundwater in the Nubia aquifer is considered to be a non-renewable resource. The results of the Nubia groundwater resource evaluation in the Western Desert indicate the availability of sustainable and economic groundwater for 100 years in the New Valley Oases at an extraction rate of 1.045 bcm/year. Groundwater model studies showed that in the East Oweinat area and Siwa Oasis, groundwater can be exploited from the Nubia Sandstone Aquifer at an annual rate of 1.2 bcm and 0.14 bcm, respectively, over 100 years. A full economic evaluation of the groundwater use in these two areas has not yet been done. (See EPIQ Report # 10 for more details.)

2.1.1.5 Free-Flowing Groundwater*:* The Nubia Sandstone sequence outcrops in the southwestern part of the Western Desert, where it behaves as an unconfined aquifer, while northwards, it disappears under a thick low permeability cover and functions as a confined to semi-confined aquifer. This latter part of the aquifer provides for the free-flowing conditions that exist in wells drilled into the Nubia Sandstone. The development and utilization of free-flowing groundwater began centuries ago with the springs of the original oases of the Western Desert. Large-scale development began in the 1960s, when wells were initially discharging free-flowing water at a rate of 5,000 to 30,000 $m^3$/day with pressure of 5 to 8 atmospheres at ground surface. In the areas of Dakhla, El-Farafra and Siwa Oases, naturally free-flowing groundwater conditions currently occur. Because of problems with collapsing wells due to high back pressures during rapid valve closure, wells are not shut off daily. In fact, the discharge is not even reduced at night when the water is not used for irrigation. This results in uncontrolled and continuous flowing wells causing water wastage, water logging and soil salinization.

### 2.1.2 Brief History of Development and Utilization

2.1.2.1 Background*:* Even in ancient times, natural spring water originating from the Nubia Sandstone Aquifer system was used in the Western Desert oases. More recently, but prior to 1960, the water supply from the springs was supplemented by construction of shallow wells with depths from 50-70 m. These wells tapped the uppermost horizon of the aquifer using cable tool drilling techniques and wooden log lining made from the dome trees.

After 1960, wells between 300 and 1,200 m depth were drilled to extract water from the deep aquifer horizons in order to provide water supplies for proposed large scale irrigated agriculture and new settlements in the New Valley (El-Kharga, El-Dakhla, El-Farafra and El-Bahariya Oases). These deep wells are the primary focus of this report.

2.1.2.2 Groundwater Extractions*:* The groundwater extractions during the period 1960 to 1997 from the Nubia Sandstone Aquifer system are presented by area in Table (1). The data given in this table were based on the observed discharges of the individual wells, which were measured every three months. Well observations were carried out by the General Authority for Rehabilitation Projects and Agriculture Development (GARPAD) and the New Valley Development Authority (NVDA) until mid-1995, after which the New Valley Water Resources Development Department (NVWRDD) of the MPWWR took over this responsibility.

Table (1) indicates that the total annual groundwater extraction from the shallow and deep wells tapping the Nubia Sandstone Aquifer was 203 mcm in 1960 (from 1,043 shallow wells and 27 deep wells) and increased to 678.7 mcm in 1997 (from 904 shallow wells and 692 deep wells). Presently 271.7 mcm are extracted from 1,516 shallow wells and springs from the post-Nubia fractured carbonate aquifers in El-Farafra and Siwa Oases.

In El-Kharga Oasis, prior to 1938, groundwater extraction was confined to the uppermost horizon of the Nubia Sandstone Aquifer through the natural springs and shallow wells (50 to 70 m deep). Exploitation of deep aquifer horizons in the Oasis began during the period 1938-1952, when seven deep wells (300-500 m deep) were drilled as combined test and production wells. In 1960, when large-scale land reclamation started in the New Valley, development of groundwater from the deep horizons with free-flowing conditions was started in order to supply irrigation water and to avoid over-exploitation of the shallow aquifer horizon, previously the only source of water for the native's cultivated lands.

2.1.2.3 Aquifer Response*:* In the reclaimed areas of the Western Desert Oases, groundwater monitoring indicates that exploitation of groundwater from the Nubia Sandstone Aquifer usually starts with free-flowing conditions. Over time, as groundwater extraction rates increase, artesian pressures decrease, resulting in the need for pumping. In this section, the example of trends in aquifer response to the groundwater extractions in El-Kharga Oasis is given. For greater detail and for other areas of the Western Desert, see EPIQ/WPRP Report #10.

Table (1) indicates that 12 deep wells and 279 shallow wells and springs were in use in El-Kharga Oasis in 1960. The 1960 water yields were 15.8 and 36.9 mcm from deep wells and shallow wells and springs, respectively, for a combined total of 52.7 mcm. During the period 1960-1997, the number of deep wells increased to 192, while the number of shallow wells and springs decreased to 16. The corresponding 1997 water yields were 119.1 and 2.2

Table (1). Groundwater Extraction from the Nubia Sandstone Aquifer in the Western Desert during the Period 1960-1997 (mcm).

mcm, respectively, for a combined discharge of 121.3 mcm.
Figure (2) shows these trends graphically. This figure indicates that the average daily discharge of the free-flowing deep wells has decreased from 3,598 $m^3$ in 1960 to 1,400 $m^3$ at present. The rate of decline has been 61 percent during this period. Out of 185 deep wells in El-Kharga Oasis, 180 wells are currently pumped, and only 16 shallow wells are still free-flowing. These data clearly indicate the decrease of potentiometric levels in the upper zones of the aquifer. The results of groundwater monitoring in El-Kharga Oasis during the last 35 years show that a rate of decline in groundwater potentiometric elevations ranged between 0.13 and 2.2 m/year.

### 2.1.3 Current Status of Development and Utilization

Total groundwater extraction in the Western Desert in 1997 was about 0.7 bcm (Tables 2 and 3) from the Nubia Sandstone Aquifer and about 0.3 bcm from the Upper Cretaceous/Tertiary carbonate aquifer systems in El-Farafra and Siwa Oases. This water included flow from 1,636 uncontrolled, continuously flowing wells in the reclaimed areas of El-Dakhla, El-Farafra, and Siwa Oases. It is estimated that 92 percent of this total groundwater extraction is used for agriculture. The present total reclaimed area under irrigation using the Nubian groundwater is 105,000 feddans, while that on the Post-Nubia aquifers is about 10,000 feddans.

Based on the potential of the Nubia Sandstone Aquifer, the available additional groundwater for future developments in the Western Desert priority areas are: 220 mcm/year in El-Farafra Oasis, 83 mcm/year in El-Dakhla Oasis, and 58 mcm/year in El-Bahariya (EPIQ/WPRP Report #10).

## 2.2 Land Reclamation and Agricultural Development in the Western Desert Oases

### 2.2.1 Design Strategies

Prior to 1960, agriculture in the Western Desert Oases was based on the use of water from structurally controlled natural springs and shallow wells tapping the upper part of the Nubia Sandstone Aquifer.

In 1960, the GOE started large-scale agricultural development in the New Valley Oases of El-Kharga, El-Dakhla and El-Bahariya, utilizing deep groundwater. The irrigator wells were spaced at 2-4 km apart to serve a localized area around the well. This system posed both a risk of crop loss, if a well failed, as well as the difficulty of transferring water from one well to another for irrigation. To overcome problems encountered with the single-well irrigation scheme, a new system was applied to the new reclamation projects in West Mawhub and El-Farafra Oasis. This new system featured a well-field with interconnected wells serving an irrigation command area.

### 2.2.2 GARPAD Strategy

Although the Nubian groundwater development in the Western Desert starts with an initial free-flowing condition, over time, and as groundwater extraction rates increase, well

Figure (2) Groundwater Extraction in El-Kharga Oasis (1960-1997).

Table (2) Available Groundwater and Present Extraction from the Nubia Sandstone Aquifer System at Different Development Areas, Western Desert.

| **Development Area** | **Present Extraction (1997) (mcm/year)** | **Total Available Economic Extraction (mcm/year)** | **Average Pumping Depth after 100 Years (m)** | **Economic Pumping Depth (m)** |
|---|---|---|---|---|
| New Valley | | | | |
| Kharga | 118 | 110 | 52 | 38 |
| El-Zayat | 3 | 14 | 66 | 62 |
| Abu Tartur Phosphate | 7 | 22 | 200 | |
| Dakhla & Mawhub West | 291 | 374 | 63 | 63 |
| Farafra & Abu Minqar | 160 | 410 | 66 | 110 |
| Bahariya | 57 | 115 | 75 | 96 |
| Total New Valley | 636 | 1,045 | | |
| East Oweinat | 31 | 1,200* (Safe Yield) | <100 | not yet defined |
| Siwa Oasis | 20 | 140** | <100 | not yet defined |
| Grand Total | 687 | 2,385 | | |

* Groundwater resources should be reevaluated to assess the economic extraction rate.
** Groundwater resources should be reevaluated to assess the sustainable and economic extraction rate that can be safely utilized without quality deterioration.

Sources: Euroconsult / Pacer Consultants, 1983
GARPAD, 1996
El-Mudallal, 1990

piezometric heads decrease, resulting in a decrease in the free-flowing discharge and the need for pumping in order to continue supplying the irrigation water requirements.

Based on the above, GARPAD (General Authority for Rehabilitation Projects and Agricultural Development), being the national entity responsible for land reclamation plans, has adopted the following strategy for reclamation projects in the Western Desert development areas:

- The area which the well can irrigate is determined by the production rate the well can efficiently maintain over its economic lifetime (20-25 years). This rate should be the rate the well can yield during its pumping stage, regardless of its initial free-flowing discharge.

- The irrigation wells should be designed to accommodate the future required pump and expected pumping levels over the economic life of the well, and should be equipped with API standard casings and stainless steel screens to ensure its long life. Table (4) shows the well design discharge rate and the area to be irrigated in the different Western Desert free-flowing groundwater areas.

**Table (3). Deep Groundwater Exploitation in the New Valley Development Areas (1997).**

| Development Area and Water Use Sector | Present groundwater extraction | | | | | | Total Number of Wells & Extraction Rate ($m^3$/day) | | Present Cultivated Area (feddans) |
|---|---|---|---|---|---|---|---|---|---|
| | Flowing Wells | | Pumped Wells | | Springs* | | | | |
| | *Number* | *Total Discharge* ($m^3$/day) | *Number* | *Total Pumpage* ($m^3$/day) | *Number* | *Total Discharge* ($m^3$/day) | | | |
| **(1) Kharga Oasis** | | | | | | | | | |
| *** Agriculture** | 5 | 7,000 | 158 | 274,000 | 16 | 6,000 | 179 | 287,000 | 17,000 |
| *** Domestic** | | | 22 | 37,000 | | | 22 | 37,000 | |
| **Total** | 5 | 7,000 | 180 | 311,000 | 16 | 6,000 | 201 | 324,000 | |
| **(2) El-Zayat** | | | | | | | | | |
| *** Agriculture** | | | 7 | 8,400 | | | 7 | 8,400 | 700 |
| **Total** | | | 7 | 8,400 | | | 7 | 8,400 | |
| **(3) Dakhla Oasis** | | | | | | | | | |
| *** Agriculture** | 239 | 357,000 | 27 | 57,000 | 505 | 165,000 | 771 | 579,000 | 30,500 |
| *** Domestic** | 39 | 48,000 | | | | | 39 | 48,000 | |
| **Total** | 278 | 405,000 | 27 | 57,000 | 505 | 165,000 | 810 | 627,000 | |
| **(4)West Mawhub** | | | | | | | | | |
| *** Agriculture** | 26 | 170,000 | | | | | 26 | 170,000 | 7,000 |
| **Total** | 26 | 170,000 | | | | | 26 | 170,000 | |
| **(5) Bahariya Oasis** | | | | | | | | | |
| *** Agriculture** | 15 | 18,000 | 29 | 51,000 | 383 | 70,000 | 427 | 139,000 | 12,500 |
| *** Domestic** | 15 | 16,000 | | | | | 15 | 16,000 | |
| **Total** | 30 | 34,000 | 29 | 51,000 | 383 | 70,000 | 442 | 155,000 | |
| **(6) Farafra Oasis & Abu-Minqar** | | | | | | | | | 14,000 |
| *** Agriculture** | 94 | 421,700 | | | 16 | 1,863 | 110 | 423,563 | |
| *** Domestic** | 3 | 14,900 | | | | | 3 | 14,900 | |
| **Total** | 97 | 436,600 | | | 16 | 1,863 | 113 | 438,463 | |
| **Grand Total** | 436 | 1,052,600 | 243 | 427,400 | 920 | 242,863 | 1,599 | 1,722,863 | 81,700 |

***And Native Wells**

**Sources: NVWRDD, 1997**
**GARPAD, 1997**

2.2.3 Future Development Plans

Based on the deep groundwater resources potential in the Western Desert, the present extraction rates for different sectors (e.g., agriculture, mining and domestic) and the additional available groundwater potentials for future development plans in the Western Desert are summarized in Table (5).

Before 1997, national large scale development activities based on the deep groundwater resources in the Western Desert were the responsibility of the GOE (GARPAD). These

**Table (4). Sustainable Well Yields and Irrigated Area in the Western Desert Free-Flowing Groundwater Development Areas.**

| Development Area | Design Well Optimum Yield* | | Irrigated Area per Well** | Remarks |
|---|---|---|---|---|
| | ($m^3$/hr) | ($m^3$/d) | | |
| El-Dakhla Oasis & West Mawhub | 300 | 4,800 | 165 | |
| El-Farafra Oasis | 450 | 7,200 | 250 | In El-Farafra Oasis, for wells equipped with 13 3/8" pump house casing, (El-Nahda, West Qasr El-Farafra) design Q=300 $m^3$/hr |
| Abu-Minqar | 400 | 6,400 | 220 | |
| El-Bahariya Oasis | 250 | 4,000 | 160 | |
| Siwa Oasis | 400 | 6,400 | 255 | |

* Well production rate is the rate of the expected future pump operated at 16 hr/day.

** Area possibly irrigated at a water requirement of 29 $m^3$/feddan/day, in the New Valley oases and 25 $m^3$/feddan/day in Bahariya and Siwa Oasis.

1. **Sources: GARPAD, 1974**
   EPIQ/WPRP Report #10

activities included the construction, operation and maintenance of well fields, pumping units, irrigation and drainage networks and well replacement. The reclaimed lands were then tenured to small farmers, graduates, cooperatives and investors. At present, the GOE is responsible for O & M of wells, well pumps, and the main irrigation and drainage networks and for well replacement in the old reclaimed areas tenured to graduates and small farmers (5-7 feddans).

Since 1997, the GOE has encouraged private sector participation in different development sectors, such as land reclamation and mining activities, in the Western Desert areas. A total of 235,000 feddans were allocated to be reclaimed by the private sector in the East Oweinat (200,000 feddans) and Karawein plain of El-Farafra Oasis (35,000 feddans).

### 2.3 Detailed Problem Description

In the Western Desert oases of El-Dakhla, El-Farafra and Siwa, deep wells are characterized by high initial free-flowing discharges (5,000 to 30,000 $m^3$/day) and artesian pressures (5-8 atmospheres at the wellheads). In these Oases, a total of 1,636 uncontrolled, continuously-

**Table (5). Groundwater Potentials and Land Reclamation Plans in the Western Desert Oases.**

| Development Area | Present GW. Extraction (mcm/yr) | Available Future Extraction (mcm/yr) | Land Reclamation Plan (feddans) | | Remarks |
|---|---|---|---|---|---|
| | | | Present Reclaimed Area | Future Expansion | |
| Kharga Oasis | 118.0 | | 17,000 | | Present extraction exceeds economic extraction rate |
| El-Zayat | 3.0 | | 1,200 | | Well field exsists but only 700 feddans are cultivated at present |
| Abu-Tartur Phosphate Mine | 7.0 | 15.0 | | | Used for domestic and ore benefication |
| El-Dakhla Oasis & Mawhub West | 291.0 | 83.0 | 37,500 | 18,500 | |
| El-Farafra Oasis & Abu-Minqar | 160.0 | 220.0 | 31,000 | 35,000 | Irrigator well fields exist to yield 190 mcm/year when in full operation |
| El-Bahariya Oasis | 57.0 | 58.0 | 12,500 | 8,000 | |
| East Oweinat | 30.0 | 1,170.0 | 7,000 | 182,000 | Economic GW extraction is not yet assessed |
| Siwa Oasis | 20.0 | 120.0 | | 17,000 | Economic GW extraction is not yet assessed |
| Total | 686.0 | 1,666.0 | 106,200 | 260,500 | |

Sources: New Valley Water Resources Development Department
Pacer/Euro consult Consultant, 1983
DRTPC, 1984
EPIQ/WPRP Publication # 10, 1998

flowing deep wells produce at an annual rate of 0.675 bcm. As such flowing groundwater is not properly controlled nor optimally utilized, serious environmental problems are occurring, as summarized in the following section.

#### 2.3.1 Groundwater Wastage

- The wells in areas where free-flowing groundwater conditions prevail, are usually kept continuously flowing 24 hours a day. The users irrigate only during daylight hours and there are no on-line storage facilities to handle nighttime well flows. As a result, about 0.3 bcm/year is wasted. Moreover, due to lack of well flow control, large quantities of water are wasted when irrigation demand is low in the middle of the winter season, prior to and just after planting and around harvesting.
- In El-Farafra Oasis (Shiekh Marzouk reclaimed area), the wells have been allowed to flow continuously at discharge rates greatly exceeding the well design discharge for irrigation. This results in an increase in the rate of well pressure decline and a decrease in the well free-flowing discharge, such that the well ceases flowing sooner than anticipated. The wells located at higher ground surface elevations are the first to cease flowing (Figure 3).
- Well failure problems occur if the valves on the wells are closed suddenly, due to a transient pressure surge (commonly called water hammer) which can result in the collapse of the formation around the well screens.

#### 2.3.2 Maintenance Problems/Issues

Lack of maintenance of the free-flowing wellhead (which includes control valves, flanges and discharge pipes) renders well flow regulation rather difficult and leads to excess water wastage and serious environmental impacts.

- Although the Nubian groundwater is fresh, hydrogeochemical studies have indicated that it is severely corrosive to normal steel components of the well and pump. This is mainly due to the presence of $CO_2$, $H_2S$ and the relatively low pH and redox potential (Clark, 1962). Also, these dissolved gases were found to attack the well casings up to a depth of 50 m. Design of deep wells in the Western Desert now incorporates the use of the API standard casings and stainless steel screens as well as the installation of double cemented casings in the upper 50 m of the well profile.
- Incrustation of organic and inorganic materials upon the surfaces of well and wellhead components leads to an increase in surface roughness which changes the water velocity.
- The Nubian groundwater is characterized by the presence of dissolved hydrated iron, with the maximum concentration in El-Farafra -- Abu-Minqar area (5-20 mg/l). The hydrated iron is immediately precipitated when exposed to the atmosphere. This results in the failure of modern irrigation technology such as drip irrigation, due to the clogging of emitters by the iron oxides.

### 2.4 Institutional/Regulatory Control and Measures for Groundwater Management

#### 2.4.1 Current Institutions

- During the period 1960-1994, several institutions have been involved in the planning, implementation, operation and management of the groundwater facilities in the Western

Desert. These are: the General Desert Development. Organization (GDDO) (1959,1970), the Desert NVWRDD of the Ministry of Agriculture, Irrigation and Land Reclamation (1970-1978), the General Authority for Rehabilitation Project and Agriculture Development (GARPAD) of the Ministry of Agriculture and Land Reclamation (1978-1994).

- Since 1994, in accordance with Presidential Decree No. 395 of 1994, evaluation, planning, development, operation, maintenance, management and monitoring of groundwater resources in the Western Desert and the North Western Coastal zone was completely transferred to the Central Directorate of Public Works and Water Resources of the New Valley and Matruh Governorates. The New Valley Water Resources Development Department (NVWRDD) is one of the two general departments under this central Directorate.
- Under Law 12/1984 and its bylaws issued by the Ministerial Decree No. 14717/1987, the Ministry of Public Works and Water Resources (MPWWR) has the overall responsibility for issuing well drilling and use permits.
- According to Law 143/1981, GARPAD is considered the central governmental organization responsible for the design and implementation of desert reclamation schemes which are subsequently transferred to the private sector.
- The New Valley Development Authority (NVDA) of the Ministry of Housing, New Communities and Public Utilities, is responsible for planning and construction of the drinking water and sanitation system. At present, design and construction of drinking water wells in the Western Desert settlements is carried out by the Research Institute for Groundwater (RIGW) of the NWRC, but financed by NVDA.

### 2.4.2 Recommended Institutional/Regulatory Control and Measures

- The PWWR Central Directorate for the Western Desert is mandated to plan, design, and manage groundwater resources and issue well drilling and use permits to groundwater users. However, it was noticed that, in areas recently allocated by GARPAD to be reclaimed by the private sector in El-Farafra Oasis (Karawein Plain) and in East Oweinate, groundwater facilities are being installed and managed without direct control and follow-up by the MPWWR. Close coordination between GARPAD (MALR) and NVWRDD (MPWWR) is strongly recommended to better develop, manage and control the groundwater resources in such large-scale reclamation projects (235,000 feddans).
- The well maintenance campaign and installation of discharge measurement facilities, which have been started by NVWRDD in some parts of El-Farafra Oasis, should be extended to other areas of free-flowing groundwater. Such extension is necessary for reducing water wastage and enabling continuous well flow control and regulation.
- The available well hydrologic data of the Western Desert development areas indicated poor or almost no regular groundwater monitoring programs over the last decade, especially in El-Dakhla, El-Farafra and El-Bahariya Oases. This may be attributed to the lack of technical staff and desert vehicles. This results in the difficulty of controlling groundwater wastage, predicting the long-term aquifer response to extraction, and forecasting the period the groundwater will continue free-flowing. A regular and systematic groundwater monitoring program for extraction rates, potentiometric levels, and water quality is of vital importance and should be considered an integral part of groundwater management in the Western Desert. This will necessitate strengthening NVWRDD capacity with the necessary technical manpower and modern measuring devices.

- Participation of the private sector in the reclamation of new desert lands should be encouraged, but with very close control and follow-up from the MPWWR regarding well permitting, planning (well field and well design), implementation and utilization of the groundwater facilities. Moreover, it is recommended that well flow control and regulation in the existing reclaimed areas be the full responsibility of the MPWWR. The free-flowing well discharge should match the crop irrigation requirement without exceeding the design future pumping rate.

# 3 METHODOLOGY

## 3.1 Problem Assessment

### 3.1.1 Selection of El-Farafra

The proper management of free-flowing groundwater in the Western Desert Oases requires the development and adoption of policies and procedures for reducing groundwater loss and land degradation in the reclaimed areas. To achieve such objective, the EPIQ groundwater working group selected El-Farafra Oasis (Figure 4) for the development of the policy package for free-flowing groundwater management. Reasons for this selection include:

- Free-flowing groundwater from the Nubia Sandstone Aquifer in the Western Desert occurs in the Oases of El-Farafra, El-Dakhla and El-Bahariya and Siwa. Over time, groundwater levels have declined and wells have had to be equipped with pumps to extract groundwater. This has occurred primarily in El-Kharga Oasis (98% of wells are being pumped at present) and somewhat in El-Dakhla Oasis (23% of wells started pumping).
- Free-flowing well discharges and pressures are relatively lower in El-Dakhla compared to El-Farafra, where deep wells discharge groundwater at higher rates (10,000 to 30,000 $m^3$ per day) and at considerably higher pressures (5 to 8 atmospheres at wellhead) with no well flow control measures. This result in significant groundwater wastage.
- In El-Farafra Oasis, the total reclaimed area is 31,000 feddans. However, just 12,000 feddans in the command area are currently under cultivation. The result is availability of water to agriculture at nearly twice the rate required. Serious drainage problems and groundwater wastage are occurring.
- Development plans for El-Farafra indicate a potential increase of reclaimed area to about 66,000 feddans in the near future, as private sector development in the Karawein plain area (35,000 feddans) occurs. This requires immediate development of policies to provide guidance on proper management of free-flowing groundwater in irrigation to mitigate adverse environmental effects and negative impacts on agriculture production in the Oasis.
- There are serious drainage and land degradation problems occurring in Siwa Oasis. These problems are primarily due to uncontrolled, poorly designed and poorly distributed wells tapping the limestone aquifer (as opposed to the Nubia Sandstone Aquifer) in that area. This situation is currently being investigated by the Research Institute for Groundwater (RIGW).
- It is intended that the policy package and procedures developed in El-Farafra can be adapted and extended to other areas where free-flowing groundwater from the Nubia Sandstone Aquifer system occurs.

### 3.1.2 Description of the Reclaimed Areas in El-Farafra Oasis

Before 1965, the source of water supply in El-Farafra Oasis was confined to 23 springs originating form the upward flow of groundwater form the Nubia Sandstone Aquifer along fault plans, fractures and joint systems and through the over lying shales or chalky limestones. At present the number of active springs has decreased to 16, with a total annual discharge of 0.68 mcm.

**2. Figure (4). Location of Reclaimed Areas Within El-Farafra-Abu-Minqar**

In 1982, the GOE started a land reclamation program in El-Nahda and Abu-Minqar areas of El-Farafra Oasis followed by the West Qasr and El-Sheikh Marzouk areas during the period 1985-1995. Table (6) and Figure (4) show the locations of reclaimed areas in El-Farafra--Abu-Minqar, the numbers of drilled wells, the gross reclaimed area and the cultivated areas during the winter season 1998/1999.

An additional area of 35,000 feddans was already allocated to be reclaimed by the private sector in Karawein and Baraka plains. Two deep test-productive wells were drilled by GARPAD in the Karawein plain to investigate the hydrogeologic setting of the Nubia aquifer, and to give technical guidelines for the optimum designs of wells and well fields in the area.

#### 3.1.3 Selection of Case Study/Pilot Area

After a reconnaissance field trip to El-Farafra Oasis in early October 1998, the groundwater working group, along with the New Valley Water Resources Development Department (NVWRDD) staff, selected West Qasr El-Farafra reclaimed area as a model study area for development of the groundwater management policy package.

The selection of West Qasr El-Farafra as a case study/pilot area for development of policies for management of free-flowing groundwater wells can be justified as follows:

- The area is considered to be of very high free-flowing groundwater potential, as the existing wells have been discharging at high rates since 1987 and are predicted to continue flowing for a long time due to the aquifer hydrogeologic characteristics and low topography.
- Wellhead maintenance for 8 wells was recently completed by the NVWRDD in addition to the construction of a water collector basin and the installation of V-notch weirs for well discharge measurements. However, wells in other reclaimed areas of Shiekh Marzouk and Abu-Minqar still need installation of discharge measuring devices.
- Due to uncontrolled excess flowing groundwater, the area is badly suffering from drainage, soil salinization and water wastage problems, which are the main issues of the benchmark.
- As previously indicated, the reclaimed area of West Qasr El-Farafra is approximately 2,565 feddans served by 12 free-flowing wells, of which 10 are in operation at present, discharging at a rate of 148,972 $m^3$ per day (about 54 mcm/year) and serving about 1,825 feddans.

## 3.2 Field Studies

During the course of the current activity, several field visits were made by the working group to the central Western Desert Oases in general, and El-Farafra Oasis in particular. These field visits enabled the working group to get familiar with the issues, to collect necessary data and information regarding the historical hydraulic performance of the existing free-flowing wells, and to make field measurements of well discharge and water salinity. The results of the field work can be summarized below.

**Table (6). Features of Reclaimed Areas in El-Farafra - Abu-Minqar, Western Desert.**

| Location | Area Reclaimed | | No. of Wells | | Remarks |
|---|---|---|---|---|---|
| | Gross Area | Cultivated Area[1] | Total | Operating | |
| Abu-Minqar | 4,000 | 1,266 | 11 | 7 | Unofficially irrigated area: 135 feddans |
| Shiekh Marzouk | 22,500 | 6,825 | 63 | 53 | Unofficially irrigated area: 4,462 feddans |
| West Qasr El-Farafra | 2,500 | 1,523 | 12 | 10 | Unofficially irrigated area: 1,138 feddans |
| El-Nahda | 2,000 | 1,705 | 8 | 8 | Unofficially irrigated area: 1,441 feddans |
| Total | 31,000 | 11,319 | 94[3] | 78 | 7,176 feddans[2] |

[1] Cultivated area in the irrigation command area in winter season 1998/99.

[2] Area unofficially irrigated outside the command areas using drainage water and water leakage from the wellheads. (+ 618 feddans in El-Farafra village)

[3] Excluding 3 wells drilled for domestic uses.

### 3.2.1 Well Locations in El-Farafra Oasis

A total of 97 production wells are located in the El-Farafra--Abu-Minqar area, of which 86 wells are free-flowing, while 10 wells located in the eastern part of El-Shiekh Marzouk ceased flowing. The 80 active wells are used in irrigation while 3 wells are allocated for domestic purposes at an annual rate of 160 mcm. A number of deep test/productive wells were drilled: 3 in El-Shiekh Marzouk, and 2 in Karaween plain. Five observation wells are in El-Shiekh Marzouk, Qasr El-Farafra and El-Nahda areas. Figure (5) shows the locations of the production wells by area in El-Farafra Oasis including the Abu-Minqar area.

### 3.2.2 Well Discharge Measurements

As a result of wellhead maintenance and construction of measuring weirs, the field measurement team of NVWRDD could measure the free-flow water discharge of wells located in West Qasr El-Farafra (12 wells), Qasr El-Farafra (2 wells) and El-Nahda reclaimed area (8 wells). These measurements were carried out using the multifunction ultrasonic device, which is usually used to measure the rate of piped fluid flow. A schematic view of the instrument is shown in Figure (6). Bad wellhead conditions due to lack of maintenance, water leakage through flanges and well discharge pipes, made measurements of well discharge in El-Shiekh Marzouk and Abu-Minqar impossible.

### 3.2.3 Irrigated Areas

A field inventory of the irrigated areas in El-Farafra--Abu-Minqar area during the winter of 1998/99 indicated that the total cultivated area is 19,240 feddans, with 11,446 in the command areas and the rest (7,794 feddans) unofficially irrigated land outside the command areas. This unofficial land is cultivated by the newcomers to El-Farafra using drainage water as well as water leaking from the wellheads as their source of irrigation water. Although there is enough drainage water at present to irrigate the unofficial irrigated areas, it is expected that when the well discharges are controlled, such drainage water will not meet the irrigation requirements for the unofficial irrigated areas.

### 3.2.4 Cropping Patterns

Agriculture is the main economic activity in the New Valley. Data on the cultivated crops in El-Farafra--Abu-Minqar area, for both seasons each year, from winter 1993/94 through winter 1998/99 are shown in Tables (A-1) to (A-11) of Appendix A. The data indicate that the maximum area ever cultivated in El-Farafra--Abu-Minqar area was 21,128 feddans in the winter season 1997/98, and 10,915 feddans in the summer of 1998. They also show that the major winter crops are wheat, beans, berseem, barely, alfalfa, vegetables and onion, with minor crops of sugarcane, caraway seeds and aromatic plants. The main summer crops in the area are rice, cucumber, seeds, sesame, alfalfa, maize, sorghum and fodder.

Table (7) shows the official and unofficial irrigated areas in El-Farafra--Abu-Minqar reclaimed areas during the winter season 1998/99.

**Table (7). Official and Unofficial Irrigated Areas in El-Farafra - Abu-Minqar Reclamation Area (Winter 1998/99).**

| **3. Reclamation Area** | Gross Area (feddans) | Number of Operating Wells[1] | Irrigated Area[2] (feddans) | | |
|---|---|---|---|---|---|
| | | | Command Area | Unofficial Area | Total |
| Abu-Minqar | 4,000 | 7 | 1,266 | 134 | 1,400 |
| El-Sheikh Marzouk | 22,500 | 53 | 6,795 | 4,461 | 11,256 |
| West Qasr El-Farafra | 2,500 | 10 | 1,497 | 1,137 | 2,634 |
| El-Nahda | 2,000 | 8 | 1,705 | 1,441 | 3,146 |
| Qasr El-Farafra & Karawein Plain | | 3 | 170 | 634 | 804 |
| Total | 31,000 | 78 | 11,433 | 7,807 | 19,240 |

[1] Number of irrigation wells in use on May 9, 1999
[2] Area irrigated in winter season 1998/99

## 3.3 Process of Developing an Organization of Groundwater Users

A survey was conducted in November 1998 to assess interest in, and potential for, development of an organization of groundwater stakeholders in El-Farafra Oasis. It was concluded that a users organization would be viable and could play an effective role in improving the situation with respect to irrigation water delivery in El-Farafra Oasis. The results of the survey are highlighted in Sections 4.5 and 4.6 of this report.

# 4 CASE STUDY: WEST QASR EL-FARAFRA

## 4.1 Detailed Description of West Qasr El-Farafra

### 4.1.1 Overview

The West Qasr El-Farafra area is the second most northern of the reclaimed areas within El-Farafra Oasis, as shown in Figure (4). This area was chosen as a pilot area for development of policies and procedures for better management of the free-flowing groundwater to reduce water wastage and environmental problems. This pilot area is not entirely representative of all the many problems existing in the reclaimed areas of Egypt's Western Desert. But it can serve as a focus area with a data source for evaluating many of the possible management strategies as to their technical, social, and economic viability for utilization, conservation, and preservation of the groundwater resource.

Figure (7) shows a detailed map of the command area of West Qasr El-Farafra as well as surrounding areas of unofficial irrigation. This map shows a total currently cultivated area as 1,825 feddans. The total command area for the 10 currently operating wells based upon the GARPAD design is about 2,070 feddans, or if all 12 wells were operated, about 2,565 feddans. Details of calculating these numbers are given in Section 4.1.2. Figure (7) also gives the number of farmers served by each of the 10 currently operating wells, a total of 306 farmers for all 10 wells. Currently, about 365 feddans (summer) and about 1137 feddans (winter) outside the command area are irrigated unofficially by pumping water from the drains.

### 4.1.2 Water Supply Conditions

Technical and hydraulic data on the 12 wells located in West Qasr El-Farafra area are presented in Table (8). The locations of these wells are shown in Figure (7). At present, only 10 wells are in use for irrigation, with a total daily production of 148,972 $m^3$, to serve the command area of about 1,825 feddans (No. 17 and 23 not used). Well No. 23 is partially opened to supply the required domestic water only.

Tables (4) and (8) can be used to calculate the expected winter command area according to the GARPAD design future pumping rate for the wells. Note from Table (8) that five wells (no. 7, 11, 14, 15, and 16) have $13^3/_8$-inch pump house casing. As shown in Table (4), these wells have design discharge of 300 $m^3$/hr. The other five operating wells in the study area have design discharges of 450 $m^3$/hr. The two currently unused wells, when pumped for 16 hr/day at 450 $m^3$/hr, have a total daily design discharge of 14,400 $m^3$/d. The design 16 hr/day pumping gives a daily total design flow from the 10 wells of [(300 x 5 x16) + (450 x 5 x 16)] = 60,000 $m^3$/d. Dividing this last value by an annual average irrigation water use of 29 $m^3$/d/feddans gives 2,070 feddans as the expected winter command area. A striking possibility for water savings is evident by comparing the current daily well discharge of 148,972 $m^3$ with this design value of 60,000 $m^3$. Thus, if we limit the daily well discharge to the design future pumping rate, we save 88,972 $m^3$/d or 32.5 mcm annually, which is 60% of the water currently discharged from the study area. See Section 4.4 for more discussion of these issues.

**Table (8). Technical and Hydraulic Data of Deep Wells in West Qasr El-Farafra.**

| Well No. | Location Coordiantes N - E | Ground Elevation (m.a.m.s.l.) | Date Complete | Total Depth | Casing | | Screen | | Initial Dischar ($m^3/d$) | Initial Pressure (m.a.g.l) | Present* Discharg ($m^3/d$) | Current Use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Size | Depth | Size | Interval | | | | |
| 7 | 2994.650 - | 60.18 | Apr-67 | 785 | $13^3/_8$ $9^5/_8$ | 0 - 122 122 - | $7^1/_2$ | 450-785 | 8,660 | 89.6 | 10,822 | Irrigation |
| 11 | 2993.300 - | 61.04 | May-67 | 603 | $13^3/_8$ $9^5/_8$ | 0 - 120 120 - | $7^1/_2$ | 400-603 | 13,41 | 91.0 | 12,240 | Irrigation & domestic |
| 14 | 2994.000 - | 61.75 | Feb-86 | 802 | $13^3/_8$ $9^5/_8$ | 0 - 149 149 - | $6^5/_8$ | 519-802 | 6,000 | | 11,160 | Irrigation |
| 15 | 2993.400 - | 62.84 | Apr-86 | 803 | $13^3/_8$ $9^5/_8$ | 0 - 125 125 - | $6^5/_8$ | 588-803 | 12,00 | 89.2 | 11,330 | Irrigation |
| 16 | 2995.800 - | 61.04 | Aug-87 | 799 | $13^3/_8$ $9^5/_8$ | 0 - 117 117 - | $6^5/_8$ | 565-799 | 31,17 | | 11,376 | Irrigation |
| 17 | 2994.600 - | 61.00 | June-86 | 803 | 16 $11^3/_4$ | 0 - 123 123 - | $8^5/_8$ | 510-803 | 16,80 | 89.2 | 14,800 | Not in Use |
| 18 | 2992.200 - | 61.00 | Feb-87 | 801 | 16 $11^3/_4$ | 0 - 117 117 - | $8^5/_8$ | 420-801 | 31,37 | 90.6 | 20,376 | Irrigation |
| 19 | 2992.200 - | 64.03 | Jan-87 | 803 | 16 $11^3/_4$ | 0 - 118 118 - | $8^5/_8$ | 533-800 | 23,50 | 82.6 | 17,600 | Irrigation |
| 20 | 2990.400 - | 66.15 | May-87 | 781 | 16 $11^3/_4$ | 0 - 118 118 - | $8^5/_8$ | 425-780 | 29,02 | 87.1 | 19,152 | Irrigation |
| 21 | 2989.500 - | 66.00 | May-87 | 781 | 16 $11^3/_4$ | 0 - 117 117 - | $8^5/_8$ | 405-780 | 29,18 | 86.4 | 17,856 | Irrigation |
| 22 | 2995.000 - | 66.00 | June-87 | 800 | 16 $11^3/_4$ | 0 - 117 117 - | $8^5/_8$ | 570-800 | 29,04 | 84.3 | 17,060 | Irrigation |
| 23 | 2994.400 - | 68.77 | June-87 | 804 | 16 $11^3/_4$ | 0 - 118 118 – 520 | $8^5/_8$ | 520-804 | 34,80 | 87.3 | 18,000 | Partially for Domestic Use Only |

*Total free-flowing well discharge

Table (9) shows the well production data regarding their discharges and pressures over time since they were drilled and completed. Although the wells were recently maintained and prepared for discharge measurement, they were not equipped for well pressure measurements at the wellheads.

The current annual well free-flowing discharge of the 10 operating wells in West Qasr El-Farafra is 54.4 mcm. This compares with 77.9 mcm/year for the initial conditions, which indicates an average decline in well discharge of about 2 mcm/year during groundwater extraction period of 12 years.

It should be pointed out that due to a lack of current pressure measurements in El-Farafra Oasis, it was difficult to establish the well pressure response with time and to predict its future trend and the time at which the wells will cease flowing in West Qasr El-Farafra.

### 4.1.3 Irrigation and Drainage Facilities

The West Qasr El-Farafra study area has a network of canals to convey the water from the wells to the irrigated land and is drained by a similar network of drains as shown on Figure (7). The irrigation canals are of two orders: (1) main canals collecting irrigation water from wells, and (2) branch canals receiving water from the main canals and delivering it to the cultivated lands. There are also two categories of drains: (1) main drains conveying the drainage water to a drainage pool, and (2) branch drains parallel to the branch canals. The water from the main drains is discharged to the drainage pool by using a pump station located at the end of the main drain (Figure 7). The surface area of the drainage pool is about 200 feddans. It is estimated that about 78,000 $m^3$/d of water in the winter season and 35,000 $m^3$/d in summer is currently being pumped into the drainage pool.

There are 11 main canals designed to receive water from a total of 12 wells in the study area. Some of the canals obtain water from more than one well. Details are shown in Table (10), which also includes the length of each of the main canals. The total length of all the main canals is 19.3 km. The total length of all the branch canals is 39.5 km. A similar analysis of lengths of main and branch drains was conducted for this area. A summary of lengths of canals and drains is given in Table (11), which shows total lengths of main and branch drains as 20.0 and 34.75 km, respectively.

The main canals of West Qasr El-Farafra are designed so that they have the capacity not only to convey irrigation water but also to store overnight well flow at the design future pumping rate. This design rate for the 10 wells was calculated as 60,000 $m^3$/d. Now suppose we deliver this daily rate from the continuously flowing wells at a constant rate over the full 24 hours. The required storage volume for nighttime well flow depends upon the total daily hours of irrigation. The relationship between $V$, the required storage volume ($m^3$) and $h_i$, the total daily time of irrigation (hr), is written in equation form as:

$$V = 60{,}000\left(1 - \frac{h_i}{24}\right)$$

***Table (12) shows the required storage volume as a function of the total hours of irrigation per day.***

**Table (9). Historical Well Production Data for West Qasr El-Farafra.**

| Well Name | Date of Completion | Observed Well Hydraulic Data | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Potentiometric Level (m.a.m.s.l.) | | | | Discharge ($m^3$/day) | | | |
| | | Initial | 1978 | 1983 | 1998 | Initial | 1978 | 1983 | 1998 |
| Well 6* | 12.10.66 | 148.9 | 146.1 | 143.00 | | 19,330 | 14,378 | 5,440 | 5,220 |
| Well 7 | 4.4.67 | 157.8 | 151.2 | 145.80 | | 8,660 | 8,338 | 7,776 | 10,822 |
| Well 11 | 29.5.67 | 152.0 | 150.6 | 149.70 | | 13,410 | 13,527 | 14,688 | 12,240 |
| Well 14 | 11.2.86 | | | | | 6,000 | | | 11,160 |
| Well 15 | 15.4.86 | 152.0 | | | | 12,000 | | | 11,330 |
| Well 16 | | | | | | 31,175 | | | 11,376 |
| Well 17 | 28.6.86 | 150.2 | | | | 16,800 | | | 14,800 |
| Well 18 | 10.2.87 | 151.6 | | | | 31,370 | | | 20,376 |
| Well 19 | 31.1.87 | 146.6 | | | | 23,500 | | | 17,600 |
| Well 20 | 27.5.87 | 153.3 | | | | 29,020 | | | 19,152 |
| Well 21 | 26.5.87 | 152.4 | | | | 29,180 | | | 17,856 |
| Well 22 | 17.6.87 | 150.3 | | | | 29,040 | | | 17,060 |
| Well 23 | 14.6.87 | 156.1 | | | | 34,800 | | | 18,000 |
| El-Farafra El-Balad** | 29.7.66 | 150.6 | 145.6 | | | 13,460 | 11,868 | | 7,110 |

Sources:

- GARPAD, 1982
- il Nuovo Castro Co., 1984
- NVWRDD, 1998

* Well is used to supply irrigation water for areas cultivated by natives.

** Well used for domestic supply

**Table (10). Main Canal Lengths and Supply Wells.**

| No. of Canal | Well No. | Length of Canal (km) |
|---|---|---|
| 1 | 11 & 15 | 0.75 |
| 2 | 11 & 14 | 2.00 |
| 3 | 7 & 14 | 1.90 |
| 4 | 7 & 16 | 1.50 |
| 5 | 16 & 17 | 0.70 |
| 6 | 22 | 0.95 |
| 7 | 23 | 2.50 |
| 8 | 20 | 2.00 |
| 9 | 21 | 3.00 |
| 10 | 19 | 2.20 |
| 11 | 18 | 1.80 |
| | | Total 19.3 |

**Table (11). Lengths of Irrigation and Drainage System Channels.**

| Type of Channels | | Length (km) |
|---|---|---|
| Canals: | Main | 19.30 |
| | Branch | 39.50 |
| Drains: | Main | 20.00 |
| | Branch | 34.75 |

**Table (12). Required Storage Volume for Nighttime Well Flow as a Function of Total Daily Irrigation Hours.**

| Irrigation (hr/d) | Storage Volume ($m^3$) |
|---|---|
| 10 | 35,000 |
| 12 | 30,000 |
| 14 | 25,000 |
| 16 | 20,000 |

Figure (8) presents a typical cross section for the main canals. The bed width is 0.80 m and the side slopes are 1.5:1. Depth of water in the canals during the day (irrigation time) is 0.70 m. Maximum storage water level is at a depth of 1.20 m, with freeboard of 0.50 m above this maximum water level. The trapezoidal storage area has bases of 2.9 and 4.4 m and an altitude (water depth difference) of 0.5 m, giving an area of 1.83 $m^2$. Multiplying by the total length of main canals (19.3 km) results in storage capacity of 35,200 $m^3$. Thus, for total daily irrigation of at least 10 hours, the existing main canals of West Qasr El-Farafra can store nighttime well flows at the daily discharge of continuously flowing wells equal to the design future pumping daily discharge.

Total Length of the Main Canal is 19.3 km.

Figure (8) Typical Cross-Section of Main Canals I the West Qasr El-Farafra Reclaimed Area.

4.1.4 Irrigation Water Requirements

4.1.4.1 Crops and Cropping Patterns: A wide range of crops are currently grown in the reclaimed areas of the Western Desert Oases. It may be somewhat of a surprise that such a large water user as rice is a significant crop in the desert. Data on El-Farafra Oasis cropping patterns (area for each crop) are given in Appendix A, Tables A-1 through A-11, for both the winter and summer cropping seasons beginning with winter 1993-94 through 1998-99. Table (13) shows the crops and the area planted to each crop in West Qasr El-Farafra for five winter and summer seasons from winter 1993/94 through summer 1998, except for summer 1996, for which the data are missing. This table also shows the total areas of all crops for each season, percent of the total area in each crop, and the five-year average area in each crop, total area, and percent of total in each crop. For the two groups, winter vegetables and specialty crops, the actual crop area listed for crops within each group may not be accurate, but the total area for each group is accurate. For example the value listed for caraway seed in winter 1997/98 may have included other specialty crops not on the list. Note that the average area of winter crops is about 2,185 feddans while for summer crops this average area is about 1570 feddans.

4.1.4.2 Crop Consumptive Use*:* The consumptive use (sometimes called crop water requirement) was determined for each crop in each season. These data are summarized in Table (14). This table can be used together with the 5-year average crop distribution of Table (13) to produce a monthly crop irrigation requirement for the West Qasr El-Farafra study area, which is given in Table (15). In this table the combined conveyance and application efficiency was assumed to be 60 percent. Note that the maximum monthly demand (July) is 2,924,890 $m^3$/mo which requires an average daily flow of 94,351 $m^3$/d. The total annual crop irrigation requirement is 19,134,830 $m^3$/yr at an average daily rate of 28.9 $m^3$/feddan/d.

4.1.4.3 Comparison of Crop Irrigation Requirement with Current Well Discharge*:* As noted in Section 4.1.2, the current daily well discharge from the 10 operating wells in West Qasr El-Farafra is 148,972 $m^3$/d, which on an annual basis is 54,374,780 $m^3$. Table (15) gives the annual crop irrigation requirement (average five-year cropping distribution on both official and unofficial irrigation) of 19,134,830 $m^3$. From these values, we can estimate that 35,239,950 $m^3$/yr more water is being brought to ground surface (*i.e.,* discharged from the aquifer) than is needed within the command area to meet crop irrigation requirements. Thus, about 35 mcm/yr of water (about 65% of the 10-well combined total flow) is being wasted in West Qasr El-Farafra under current conditions.

4.1.5 Domestic and Other Water Requirements

Domestic water for El-Farafra city and the settlements in El-Shiekh Marzouk and Abu-Minqar are supplied from three deep wells discharging at a rate of 14,900 $m^3$/day. The settlements in West Qasr El-Farafra are provided with domestic water from wells 11 and 23.

4.1.6 Comparison of Water Requirements with Supply

4.1.6.1 Temporal Considerations*:* In this section we will compare the crop irrigation requirements in West Qasr El-Farafra with the supply of water from the free-flowing wells as they are currently operated and also with the water supply using the design future pumping rate. As Noted in the foregoing Section 4.1.4.3, the current well flow is about 54 mcm/yr.

Table (13) Cropping Distribution for Winter and Summer for Each of Five Years (1993-98) and the Five-Year Average (feddans).

**Table (14). Consumptive Use of Crops in El-Farafra Oasis in $m^3$/feddan.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Tot. | * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Winter crops:** | | | | | | | | | | | | | | |
| Alfalfa | 410 | 450 | 620 | | | | | | | 745 | 570 | 445 | 3,240 | 1 |
| Berseem | 450 | 495 | 685 | 860 | | | | | | 430 | 510 | 490 | 3,920 | 1 |
| Barley | 495 | 495 | 325 | | | | | | | | 480 | 500 | 2,295 | 2 |
| Beans | 495 | 345 | | | | | | | | 320 | 460 | 540 | 2,160 | 1 |
| Fenugreek | 230 | 265 | 300 | | | | | | | | | 285 | 1,080 | 2 |
| Wheat | 495 | 510 | 310 | | | | | | | 330 | 385 | 520 | 2,550 | 1 |
| W. Vegetables | 500 | 500 | 360 | | | | | | | 600 | 600 | 500 | 3,060 | 1 |
| Lentil | 357 | 357 | 151 | | | | | | | 59 | 202 | 378 | 1,504 | 2 |
| Sugarcane | 25 | 52 | 580 | | | | | | | 783 | 496 | 291 | 2,227 | 3 |
| Specialty crops | 420 | 399 | 273 | | | | | | | | | 146 | 1,238 | 2 |
| **Summer crops:** | | | | | | | | | | | | | | |
| Alfalfa | | | | 780 | 990 | 1,015 | 1,115 | 1,015 | 875 | | | | 5,790 | 1 |
| Sorghum | | | | | 365 | 675 | 820 | 630 | | | | | 2,490 | 1 |
| Maize | | | | | 206 | 638 | 641 | 680 | 147 | | | | 2,312 | 2 |
| Sesame | | | | | 420 | 995 | 1,290 | 855 | | | | | 3,560 | 1 |
| Sunflower | | | | | 197 | 1,101 | 1,144 | 203 | | | | | 2,645 | 3 |
| Rice | | | | 450 | 1,150 | 1,340 | 1,470 | 1,070 | 500 | | | | 5,980 | 1 |
| Cotton | | | 128 | 391 | 664 | 806 | 915 | 430 | 208 | | | | 3,542 | 2 |
| Cucumber seed | | | | 143 | 260 | 697 | 432 | 202 | 185 | | | | 1,919 | 2 |
| Sugarcane | | | | 891 | 1,117 | 1,153 | 1,244 | 1,125 | 985 | | | | 6,515 | 3 |
| Lentil | | | | | 575 | 945 | 890 | 176 | | | | | 2,586 | 2 |
| Peanut | | | | | 500 | 580 | 1,200 | 1,400 | | | | | 3,680 | 2 |
| Other forages | | | | | 365 | 675 | 820 | 630 | | | | | 2,49 | 1 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | 0 | |
| S. Vegetables | | | | 143 | 260 | 697 | 432 | 202 | 185 | 197 | | | 2,116 | 2 |
| | | | | | | | | | | | | | | |
| **Total** | 3,877 | 3,868 | 3,732 | 3,658 | 7,069 | 11,317 | 12,413 | 8,618 | 3,085 | 3,464 | 3,703 | 4,095 | | |

Winter vegetables include onion, peas, garlic, tomato, eggplant, green pepper, green beans, chick peas

Specialty crops inculde fennel flower, caraway seed, lupine, cumin, aromatic plants and cockle

* Data Source: 1. Technical and economic feasibility study for the reclamation of 50,000 feddans in the El-Farafra Oasis, Volume 5, Il Nuovo Castoro Consultants, December, 1985.

2. MPWWR: Table of Water Consumptive Use for Winter and Summer Crops, Middle Egypt
3. SRP Paper No. 1-4: Crop Substitution for More Efficient Water Use in Egypt.

Table (15) Total Monthly Crop Irrigation Requirement for 5-Year Average Cropping Pattern, West Qasr El-Farafra ($m^3$/mo) and Other Data.

The crop irrigation requirement is about 19 mcm/yr. Water wasted is about 35 mcm/yr or about 180% of crop irrigation requirement.

The design future pumping rate for West Qasr El-Farafra (combined daily rate for the 10 operating wells) is 60,000 $m^3$/d (Section 4.1.2) or 21,900,000 $m^3$/yr. To find the crop irrigation requirement if the free-flowing wells were controlled to the design rate, we can use a procedure similar to that in Section 4.1.4.2. The water supply must meet the crop irrigation requirement of the peak period of irrigation. Thus the cropping area cannot exceed that supported by the water supply for the peak demand period. The peak demand month in West Qasr El-Farafra is July. The summer crop area must be satisfied by the design monthly well discharge (60,000 x 31) for July of 1,860,000 $m^3$/mo.

The EXCEL spreadsheet used to produce Tables (13) and (15) can be applied to find the maximum area that can be irrigated each season. If we assume that we can use the five-year (1993-1998) average as representative for our calculations, we can add to the spreadsheet used to produce Table (15) to give Table (16), which gives results of the average crop distribution in the study area. Note that Table (16) has some extra information at the bottom. If the ten free-flowing wells flow continuously at a combined rate of 2,500 $m^3$/hr, then 60,000 $m^3$ will be discharged in 24 hours. This is the rate that matches the design pumping rate. We assume that the average cropping distribution remains constant as total cropped area changes for each given season, so that the total irrigation requirement is proportional to the total crop area. We can use this fact to calculate the area which will be in balance with available water.

Table (16) has a built in calculator in the lower right hand corner that gives the maximum area for each season that will be in balance with the design water supply during the peak month of water use of each season. In this case, the maximum winter area is about 2,185 feddans. For summer it is about 1,000 feddans. A caution is in order here. Without carryover storage from month to month, the peak month is probably too long a time period for adequate crop production. These calculations should be based on shorter peak use periods of perhaps 7 to 10 days. Such calculations are left to the future. See Section 4.4.3.1 for further discussion of this issue.

Table (17) shows the crop area distribution for each season at the maximum total areas determined by Table (16). Table (18) gives a rough schedule for month-to-month well discharge to match these maximum crop areas.

On an annual basis, the water needed from the 10 wells is about 15.5 mcm. Thus, operating these wells by adjusting well flow to match crop irrigation requirements saves about 21.9 – 15.5 = 6.4 mcm/yr (or about 29%) more water than would be discharged if the free-flowing wells were allowed to continuously discharge at the design future pumping rate.

Presently there is also a diurnal imbalance between well discharge and crop irrigation requirement. This is because the wells continuously flow at their maximum free-flow rates and are not adjusted to match crop irrigation requirement even seasonally. This means that all nighttime well flow is lost to the drains since it is neither stored for later daytime use nor used to irrigate at night. Current combined well flow of the 10 operating wells of the West Qasr El-Farafra pilot area is 148,972 $m^3$/d. If we assume that the avarage irrigation time is 14 hr/day, then 10/24 of this water is lost for irrigation within the command area (42%, or about 62,000 $m^3$/d). This water lost is more than the design future pumping rate for the 10 wells combined. Even if the ten free-flowing wells were adjusted to supply their design rate

Table (16). Calculation of Maximum Areas That Can Be Irrigated Each Season With Well Discharge Rate at Design Future Pumping Rate Based on 5-Year Average Cropping Distribution, West Qasr El-Farafra (feddans).

Table (17). Cropping Distribution Expected (feddans) in West Qasr El-Farafra If Well Discharge Is Limited to Design Future Pumping Rate.

Table (18). Verification of Maximum Areas Calculated in Table (16).

(60,000 $m^3$/d for all 10 wells combined) but allowed to flow continuously at this rate, an average of 20,000 $m^3$/d would be lost at night (60,000 x 8/24).

## 4.2 Infrastructure Rehabilitation

### 4.2.1 Wellhead Rehabilitation

Regular checking of well performance and immediate correction of problems is important for extending well life and avoiding complete well failure and the necessity of drilling replacement wells at considerable cost.

Corrosion of wellhead parts -- control valves, flanges, and discharge pipes -- usually occurs in free-flowing wells. This leads to water leakage through the corroded parts, water wastage, and development of a waterlogged area near the well in the reclaimed land, making the control and regulation of the well flow rather difficult if not impossible (Figure 9).

To overcome such problems, and to ensure better well performance, the MPWWR (NVWRDD) started a maintenance program in West Qasr El-Farafra during the past year. Field inspection showed that seven wells (7, 15, 16, 18, 19, 20, 21, and 22) in the study area needed urgent maintenance to control flow. The maintenance included changing head pipes and valves and constructing a proper shed (Figure 10) to prevent unauthorized individuals from changing the well flow. Table (19) presents costs of recently completed maintenance of these seven wells. Leaving out well No. 16, which cost substantially less than for the other six, the average cost of wellhead maintenance was about LE 24,000 per well.

**Table (19). Maintenance Costs for Seven Wells in West Qasr El-Farafra.**

| Well Number | Cost (LE) |
|---|---|
| 7 | 21,110 |
| 15 | 35,400 |
| 16 | 3,675 |
| 18 | 22,400 |
| 20 | 17,700 |
| 21 | 27,820 |
| 22 | 19,150 |
| Total Cost: | 147,255 |

It is strongly recommended that the well maintenance activity of the NVWRDD be strengthened by addition of the technical manpower, materials, and modern equipment required to perform timely continuing maintenance for all wells in the New Valley.

### 4.2.2 Water Measurement Structures

Monitoring of free-flowing well discharge rates is of vital importance to any attempt to control and well discharge. The control program requires furnishing each well site with a

Figure (9).  Photograph Showing a Leaking Well Discharge Pipe and Water Wastage.

Figure (10). Photograph Showing Typical Cage for Preventing Unauthorized Change of Well Flow.

simple water measuring structure including a water collector basin and a discharge measuring weir (Figure 11) made of noncorrosive materials (e.g., PVC or aluminum). The cost of furnishing the wells with water measuring structures is about LE 28,000 per well.

## 4.3 Well Flow Control Technologies

### 4.3.1 Manual Control

4.3.1.1 Existing Valves*:* Rapid closure of the free-flowing wells ruins the aquifer formation immediately around the well. Calculations using the largest present flow indicate that minimal surge pressure (about 2 psi (pounds per square inch)) would develop in the well casing if the valve is linearly closed over a six-minute period.

Manual adjustment of valves to change discharge of free-flowing wells is currently possible with existing valves on the wells. As long as the valve is not changed suddenly, no problem exists. Also, the existing valves can be used to close the wells so long as the closing is not done suddenly. Many people who have been associated with the free-flowing wells in the Western Desert are unconvinced of this assertion; however, most of these people support the adjustment of well discharge periodically, as long as the valve is not fully closed. Even full closure is done to provide needed maintenance to the wellhead. Performing these well discharge adjustments once a month or even once a week would not greatly affect the personnel needs of the NVWRDD.

4.3.1.2 Slow-Closing Valves*:* Manually operated valves that close slowly enough to prevent pressure surges (water hammer) associated with sudden valve closure are commercially available. In fact, fine threaded screws on manually closed valves can be specified and are readily available to prevent rapid closure. The disadvantage to using these valves for nighttime well closure is that someone must visit the well twice each day, once at the end of the daytime irrigation period to properly close the valve for the nighttime, and once early each morning to open the valve again and adjust the flow to its proper rate. Assuming that the NVWRDD must perform these tasks, such a system would require a drastic increase of personnel. For periodic flow adjustment of continuously flowing wells, existing valves can be used -- manually operated slow-closing valves are not needed for this purpose.

### 4.3.2 Automatic Control

Slow-closing valves are also available with various means of actuating the valve (initiating the valve closure), after which the valve closes automatically at preset speeds. Such automatic valves can be provided with manual actuation. Manpower needs for operating these manually actuated valves for nighttime well closure is the same as described in Section 4.3.1.2. Hence there is no advantage of a manually actuated automatic slow-closing valve over a cheaper, manually operated nonautomated one. Automatic, slow-closing, remotely actuated valves are also available. The disadvantage of these is that most require a dependable supply of electricity at each well; they are fairly sophisticated and complicated so maintenance could be a problem; and their cost is much higher than manually operated valves.

Figure (11). Photograph Showing the Stilling Basin for Flowing Wells and the V-Notch Weir to Measure the Well Discharge.

The use of remotely actuated, automatic slow-closing valves needs further detailed study. Time did not allow conduct of such a study during the development of the policies of this benchmark. A research and demonstration study should be conducted by the RIGW, including field installation and evaluation of the most promising technology available. The field installation and evaluation phase should collect data for a minimum period of one year, spanning two complete irrigation seasons. Based upon results of such a project, a reevaluation should be conducted of the use of such valves for flow regulation (and/or possibly nighttime closure) of the free-flowing wells. Implementation of an alternate to nighttime well closure, to prevent wastage of nighttime well flows, should begin immediately and not wait on the results of the research and demonstration project.

## 4.4 Water Management Alternatives

### 4.4.1 Brief Background Review

The nonrenewable groundwater of the Nubia Sandstone Aquifer is the only source of water in the Western Desert of Egypt, where agriculture and mining development activities are practiced. In El-Dakhla, El-Farafra and Siwa Oases, a total of 1,636 uncontrolled, continuously flowing wells are causing environmental problems, such as water wastage, waterlogging, drainage problems, and soil salinization, that seriously impact agricultural production. Present practices contribute to waste of this precious nonrenewable natural resource. That the aquifer producing the water of the free-flowing wells is not currently receiving significant recharge is well documented. Hence any development of these waters is a groundwater mining operation with a finite economic life. Strategies for achieving improved use and management of this resource are needed. New policies and procedures based on these strategies must reduce water loss and land degradation and improve the operation and management of free-flowing groundwater in the reclaimed areas of the Western Desert.

### 4.4.2 Current Practices and Conditions

Current practices of water management that are the major contributors to water wastage in the reclaimed areas are:

- The free-flowing (nonpumped) wells are allowed to flow at a constant rate that exceeds the time varying crop irrigation requirement of the command area.
- The free-flowing (nonpumped) wells are allowed to continue to flow during the nighttime hours, even though nighttime irrigation is not practiced.
- The basin or flood irrigation methods have lower application efficiencies than methods such as trickle or sprinkle.

Relatively easy changes to the first two of these practices can significantly reduce water wastage. It is considerably more difficult to reduce wastage related to irrigation methods, given the conditions existing in the reclaimed areas.

Considerable areas of land outside the command area are being irrigated by pumping water from the drains. This unofficial irrigation utilizes water of fairly good quality that would otherwise be discharged to the drainage lakes.

As the piezometric heads in the aquifer have declined, pumps have been needed on some wells in order to continue irrigation of the command area. Since the groundwater aquifer is receiving no significant recharge, piezometric head decline is a natural consequence of water withdrawals from the aquifer.

4.4.3 Possible Policies

We define crop "water requirement" as that amount of water needed to satisfy the evapotranspiration of the crops such that yields are not limited by lack of water. We define crop "irrigation requirement" as the "water requirement" plus the amount of water needed for losses due to inefficiencies of irrigation conveyance and application. Outside of the unrealistic case of 100 percent irrigation efficiency, the crop irrigation requirement will exceed the crop water requirement. In other words, there will always be some amount of drainage water to be discharged from an irrigated area.

By considering the current practices and conditions, we can develop possible policies for improved management of the free-flowing groundwater of the Western Desert. For the reclaimed areas of the Western Desert oases, it is not practical to drastically change the methods of irrigation because of various factors including the water quality, type of soils, lack of or high cost of energy supply, wind conditions, *etc*. Previous attempts to used trickle irrigation failed because of the high iron content of the water and resultant clogging of emitters. Sprinkle irrigation presents some difficulties on small land holdings and high wind conditions. Automated, high efficiency sprinkle irrigation is not well suited to such small land holdings that do not have a dependable supply of electricity. Land leveling and/or use of gated pipe furrow application systems would produce only minor reduction of water losses. Thus, significant reduction of water losses that arise because of the difference between crop irrigation requirement and water requirement is not practical. This means that there will always be drainage water to be removed from the reclaimed areas.

Policies must address both the loss of water due to unused nighttime well flow and the well discharge that is not adjusted for seasonally varying crop irrigation requirements. Periodic adjustment of well discharge is an essential element of best use of water flowing from the wells. The focus of this section is primarily on policies that directly address technical aspects of water control and management. Other policies that are necessary for the success of water management alternatives are also considered here and discussed more fully in other sections of this report. Possible policies are listed and briefly discussed in each following subsection.

4.4.3.1 Change Well Flow Periodically*:* The possible policy statement is: **"Free-flowing well discharge will be periodically (at least monthly) adjusted to match crop irrigation requirements for the crops within the command area of each particular well, with the maximum discharge not exceeding the well's design future pumping rate".**

This policy will reduce the water wastage of the current practice of allowing the free-flowing wells to flow at a constant rate that exceeds the time varying crop irrigation requirements of the command area. Without periodic adjustment of free-flowing well discharge, water in excess of irrigation needs is discharged directly or indirectly to the drains. By implementing this policy together with any policy that prevents loss of nighttime flows, the free-flowing well discharge (total daytime and nighttime flows) will be matched to the crop irrigation requirements within the command area. In this way, the considerable amount of water saved compared to current practice will be left in the aquifer for later withdrawal. Exceeding this design rate during free-flow conditions will accelerate the decline of aquifer piezometric levels and hasten the need to begin pumping.

It must be understood by all concerned with this policy adoption and implementation that restricting the maximum free-flowing well discharge to the design future pumping rate places the same constraints on crop selection during the free-flowing period as during the future pumping period. Both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply. The personnel needs of the NVWRDD will increase due to the need to adequately assess the crop water needs to be supplied by each well depending on the particular crop mix for each irrigation season in the area served by the well. An accurate survey of areas planted to each crop for each irrigation season will be needed for each well command area.

The working group decided that a program of monthly changes of well discharge is a reasonable place to start. As discussed in Section 4.1.6, time periods of shorter than one month must be used to set the well flow rate for the month of peak use. If the well flow rate for the peak month is set at the flow needed to meet the average monthly crop irrigation requirements, crops likely would not be adequately irrigated for periods of possibly 7 to 10 days of peak demand. Not satisfying the crop need during the peak period would cause a kind of deficit irrigation that could reduce yields somewhat. Figure (12) shows weekly crop irrigation requirements in West Qasr El-Farafra, estimated by disaggregation of monthly data of Table (15). Note that the last week contains one extra day (8 days for the last week of the year, 52 x 7 = 364), and hence has a higher weekly crop irrigation requirement than adjacent weeks. Adjustments can be made as field experience is gained in flow regulation. The best flow rate for any given month may be closer to the shorter-period peak demand rate within each month rather than for the average monthly demand rate. The system likely will have enough storage of nighttime flows to allow for adequate irrigation in off-peak months.

Waiting more than a month to change well discharge rate is not practical. One would have to release much more water to the drains unused or construct larger surface storage facilities to fully utilize the water for irrigation within the command area.

4.4.3.2 Storage of Nighttime Well Flow: The possible policy statement is: **"Water loss from nighttime well flow will be prevented by using surface storage either in existing canals or new storage facilities to capture these flows and release them during daytime irrigation hours".**

This policy, together with the next two policies listed here, should be considered as alternatives to prevent currently occurring losses of water from unused nighttime well flows. If this policy is adopted, the considerable amount of water saved will be left in the aquifer for later withdrawal. By implementing this policy, together with a policy that reduces loss of water by periodically adjusting well discharge to match crop irrigation requirements, the free-flowing well discharge (combined daytime and nighttime flows) will be fully used for crop production. Such a combined policy will prolong the free-flowing condition of the wells and delay the need to add pumps to the wells. Both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply.

There will be little impact on personnel needs of the NVWRDD to operate the system using nighttime storage of well flow. If the nighttime well flow is stored in the existing canals, it

Figure (12)  Estimated Weekly Crop Irrigation Requirement in West Qasr El-Farafra.

will be used directly from the canals together with the daytime well flow. If the nighttime well flow is stored in new storage facilities, the release of stored nighttime water can be handled by the WUU in cooperation with the NVWRDD. In all GARPAD designed reclaimed areas, the main canals are designed and constructed with extra capacity to handle the nighttime well flows. In other areas (e.g., old reclaimed areas of El-Dakhla Oasis), new storage facilities may have to be designed and constructed.

4.4.3.3 Night Well Closure with Slow-Closing valves*:* The possible policy statement is: **"Water loss from nighttime well flow will be prevented by installing slow-closing valves at each wellhead and closing the valves each night".**

Currently, unused nighttime well flow is discharged directly or indirectly to the drains. Thus by eliminating nighttime flow, the considerable amount of water saved will be left in the aquifer for later withdrawal. This policy will prolong the free-flowing condition of the wells and delay the need to add pumps to the wells. Both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply.

Slow-closing valves that can prevent water hammer in the wells are commercially available, so night closing of the wells is a possible alternative to storage of nighttime flows. Screw actuated manual valves that cannot be rapidly closed are available, so complicated automatic valves are not needed. The disadvantages of automatically operated valves, that are not remotely operated, include the requirement for personnel to visit each well for opening and closing the valves, just as with manually operated valves. Also, for these valves, the cost is higher and some require a source of electricity or compressed air at each well. The automatic valves are more complicated, and remote operation requires even more sophistication and cost.

There will be a significant increase of personnel needs of the NVWRDD to close the valves at each well every night and to open them and set the proper flow again each morning. Even with these slow-closing valves that prevent water hammer pressures from developing, the operation of the valves requires a technically trained person to properly set the correct flow each morning. Because of the large need for technical personnel in the field to implement nighttime well closure, storage of nighttime well flow is preferred.

The great increase of personnel needed to manually operate the valves could be eliminated by sophisticated, remotely operated valves. Such valves would require dependable sources of electricity at each well. The use of remotely actuated automatic slow-closing valves needs further study by the RIGW. Based upon results of such a study, a reevaluation should be conducted of the use of slow-closing valves for nighttime closure and/or flow regulation of the free-flowing wells.

4.4.3.4 Continuous 24-hour Irrigation*:* The possible policy statement is: **"Water loss from nighttime well flow will be prevented by requiring continuous 24-hour irrigation within the command area".**

Continuous irrigation is practiced in many other parts of the world. Users of the traditional springs of the Oases of the Western Desert practice 24-hour irrigation on a rotational basis, so it appears that a precedent for continuous irrigation exists in Egypt. By applying this policy together with a policy that prevents loss of water by periodically adjusting well discharge to match crop irrigation requirement, a considerable amount of water will be saved and will be left in the aquifer for later withdrawal. There would be no impact on personnel needs of the NVWRDD to operate the system using continuous 24-hour irrigation. Both the quantity and quality of drainage water from the command area would decrease over time, making the water in the drains less suitable for reuse as irrigation supply.

Perhaps the greatest disadvantage of continuous 24-hour irrigation is that the farmers may not be willing to adopt nighttime irrigation. Irrigation methods used by the farmers make nighttime irrigation more difficult for them than with sprinkle, trickle, or other automated methods. When comparing this alternative with storage of nighttime well flow, the latter is preferred because of the perceived problems including lack of farmer acceptance of nighttime irrigation.

4.4.3.5 Coordination for Setting Seasonal Water Delivery Schedule*:* The possible policy statement is: **"Close contacts and coordination between the MPWWR(NVWRDD), MALR(NVAD), and WUUs will be organized to solve irrigation problems and to agree upon the crop pattern and resulting water delivery schedule each season".**

Adoption and implementation of this policy will help to ensure that irrigation water is available in adequate amounts at the right time during the season to support the production of the crops within the command area. To implement policies 4.4.3.1 and 4.4.3.2 (or any other way of preventing loss of nighttime well flow), the cropping pattern must be determined at the beginning of each season, so that a proper water delivery schedule can be created. As experience is gained with the new policies, farmers will have adequate knowledge (through their respective WUU) of available water supply upon which to make sound crop selections.

4.4.3.6 NVWRDD Needs*:* The possible policy statement is: **"The NVWRDD will be strengthened and adequately budgeted for the number of trained technical personnel in different related specializations necessary for performing its roles and responsibilities".**

Adoption of this policy will ensure that implementation of policies 4.4.3.1, 4.4.3.5, 4.4.3.7, 4.4.3.9, 4.4.3.11, 4.4.3.12, and 4.4.3.14 can be successfully accomplished. While these policies will have the greatest impact on the NVWRDD budget, other policies may produce some minor impacts on NVWRDD budget needs.

4.4.3.7 Water User Organizations*:* The possible policy statement is: **"The MPWWR will continue the program for development of water user organizations in accordance with Law #213".**

The program of formation of water user organizations started in West Qasr El-Farafra should be continued throughout the reclaimed areas of the Western Desert oases. These organizations can play a significant role in ensuring success of the policies for control of free-flowing well discharge. Their anticipated role in providing seasonal information on cropping patterns planned by farmers is an essential part of implementation of the policies (especially 4.4.3.1).

4.4.3.8 Educational Program*:* The possible policy statement is: **"The MPWWR, through the Water Communication Unit, will establish an ongoing educational program, for all stakeholders and the public, on water resource issues affecting the free-flowing groundwater management in the Western Desert".**

The efforts of the Water Communication Unit should be continued in order to increase public awareness of the nonrenewable groundwater resources of the Western Desert and the need for water conservation. Before water users will accept new water conservation measures, they need to be aware that their groundwater supply is finite, not unlimited, and that their acceptance of and contribution to such measures will indeed make a difference. All stakeholders and the public must understand the concept of the common good of the resource and that wastage in one locale ultimately affects everybody.

4.4.3.9 Working Group*:* The possible policy statement is: **"A working group will be established with membership from MPWWR, MALR, and MHNC, chaired by the representative of MPWWR, to provide continuing review of issues/conditions and policies for managing the groundwater resource in the Western Desert".**

There are several issues/conditions and policies for managing the groundwater resource in the Western Desert that will need continuing attention (For example, see policy 4.4.3.10). These may best be handled by a working group of representatives of all the ministries involved.

4.4.3.10 Transition From Free-Flowing to Pumped Wells*:* The possible policy statement is: **"A clear policy will be developed defining the operating criteria for free-flowing wells and the transition from free-flowing to pumped conditions in the reclaimed areas, including criteria for when to install pumps".**

Development of this policy could be a charge given to the working group. Groundwater extraction in areas where free-flowing wells prevail will eventually require pumping. The long-term groundwater utilization plans in these areas should be based upon future pumping conditions, even though the wells are currently free-flowing. Such an approach will provide for a stable water supply for irrigation within the command area over the entire life of the groundwater production.

It must be clearly understood by all concerned that in order to sustain the agriculture of the reclaimed areas, the need for pumping of free-flowing wells will occur before the free-flowing condition actually ceases. It might be feasible to use surface centrifugal pumps during the transition (*e.g*., when the free-flowing discharge drops below the design value well flow rate of 7200 $m^3$/d) until the lift for which these pumps are capable of bringing the water to the land surface is exceeded. At that time, submersible or deep well turbine pumps will be needed.

When to install these pumps depends on economic analysis and should be the responsibility of the MPWWR. This decision should then be communicated to the proper water user organization. When the free-flowing well discharge has declined below water demands, it is probably more economical to pump the well than to replace it with a deeper well that will be free-flowing.

4.4.3.11 Automatic Slow-Closing valves*:* The possible policy statement is: **"The MPWWR, through the RIGW, will conduct a research and demonstration study of the use of remotely actuated, automatic slow-closing valves for nighttime closure and/or flow regulation of the free-flowing wells".**

The working group considered the use of slow-closing valves to close the wells at night. The team eliminated this technique from further consideration primarily because of the tremendous technical manpower need that would be placed upon the NVWRDD for opening and closing these valves at each well every day, using manually operated valves. Slow-closing valves that cannot be closed rapidly are available. Also available are manually actuated automatic valves, but they likewise would have great manpower needs.

The great increase of personnel needed to manually operate the valves could be eliminated by sophisticated, remotely operated, automatic slow-closing valves. Such valves would require dependable sources of electricity at each well. The use of remotely actuated automatic slow-closing valves needs further study, as time did not allow conduct of such a study by the working group. A research and demonstration study should be conducted by the RIGW including field installation and evaluation of the most promising technology available. The field installation and evaluation phase should collect data for a minimum period of one year, spanning two complete irrigation seasons. The corresponding minimum project period should be two years for funding and conducting the research, including startup, equipment purchase, data collection, data analysis, and reporting. Based upon results of such a project, a future reevaluation should be conducted of the use of such valves for flow regulation (and/or nighttime closure) of the free-flowing wells. Implementation of policy 4.4.3.2 or one of the two alternatives should begin immediately and not wait on the results of the research and demonstration project.

4.4.3.12 Periodic Maintenance*:* The possible policy statement is: **"A periodic maintenance program for all irrigation water facilities will be established to ensure compatible utilization, conservation, and preservation of the groundwater resources over the planned period of groundwater mining in the Western Desert".**

The major rehabilitation of wells, main irrigation canals, and main drains will continue to be the responsibility of the MPWWR for those areas cultivated by graduates and small-holders (5-7.5 feddans). Other landholders are responsible for rehabilitation and maintenance work, under the supervision and technical guidelines of the MPWWR. Minor maintenance work on field branch canals, drains, and wellheads should be the responsibility of the WUU of the respective well. The availability of short-term loans to farmers may be essential for them to carry out minor maintenance work.

4.4.3.13 No Further Growth of Unofficial Irrigation: The possible policy statement is: **"No growth in unofficial irrigation will be allowed beyond its current area or water demand".**

This policy will minimize future problems associated with decreasing quantity and quality of drainage water from the command area. Significant unofficial irrigation that uses water in the drains to irrigate lands outside the command area has developed recently in the reclaimed areas. If the areas of unofficial irrigation are allowed to continue to grow, more people will suffer from inadequate irrigation water supply as the water in the drains becomes less suitable (or even unsuitable) for irrigation.

4.4.3.14 Drain Water Reuse*:* The possible policy statement is: **"Reuse of water from the drains for irrigating lands outside the command area adjacent to the drains will be allowed so long as the quality of the water remains suitable and the land area is in balance with supply".**

As water conservation measures are implemented, both the quantity and quality of drainage water from the command area will decrease over time, making the water in the drains less suitable for reuse as irrigation supply. The irrigators of such lands must realize that the MPWWR makes no guarantees as to the quantity or quality of water available to them from this source and makes no promise to replace this source of water as it becomes less suitable (or unsuitable) for irrigation.

Water quality of the main drains in West Qasr El-Farafra is very good. Current combined total discharge of the ten operating wells greatly exceeds both the design future pumping rate and the crop irrigation requirement of the average cropping distribution for the most recent five-year period. With the current free-flowing unregulated well discharge, there is water available to irrigate far more land than is now irrigated. Considerable amounts of water in excess of crop needs is being wasted to the drains so that the TDS of the drains remains near to that of the well water.

Table 20 gives some data on the water quality of the main drain and drainage pool of West Qasr El-Farafra. There is far too little data to determine the effects of recently completed wellhead maintenance work on the seven wells described in Section 4.2.1. The average of the two measurements of TDS in the main drain is 310 ppm while in the drainage pool the average was 2,623 ppm away from the influence of newly pumped drainage water. The high TDS of the water in the drainage pool makes it unsuitable for irrigation. The water in the main drains is currently of very good quality for irrigation. Hence, there is justification for recommending this policy of allowing drain water reuse for irrigation of lands outside the command area adjacent to the main drains. It is expected to take several years after implementing the other policies for water conservation before the drain water becomes unsuitable for irrigation. Adoption of this drainage reuse policy will help to alleviate problems of drainage pool growth and associated increase of adjacent waterlogging and soil salinization. It is estimated that the current drainage pool area is about 200 feddans, with a depth of about 2.3 m.

## 4.5 Water User Participation in the Groundwater Development Program

### 4.5.1 Initial Focus Group Workshop

The results of the initial focus group workshop will be briefly reviewed here, and are given in more detail in Appendix C.

The main recommendations from this workshop were as follows:

- An overall view that groundwater user associations should be responsible for a number of functions:

  - Scheduling and distribution of well water
  - Matching cropping pattern and water requirements
  - Referring water delivery problems to appropriate service providers
  - Conflict resolution among water users
  - Participating with local authorities in solving common irrigation problems

Only a marginal number of respondents to the questionnaire felt that the user's association should be primarily responsible for system O&M.  Several of the respondents

**Table (20). Chemical Analysis of Drainage of Water in Drainage Pool and Main Drains.**

| N | 4. Source | Date | Season | pH | T.D.S. 80 °C ppm | Cl ppm | SO ppm | Ca ppm | Mg ppm | Na ppm | K ppm | Fe ppm | T.H. as Ca $CO_3$ ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Main drain before maintenance | July 98 | Summer | 8.7 | 280 | 30 | 100 | 22 | 6.8 | 71 | 15 | 0.7 | 70 |
| **2** | Main drain after maintenance | Jan. 99 | Winter | 8.9 | 340 | 45 | 120 | 28 | 7.2 | 89 | 22 | 0.76 | 70 |
| **3** | Drainage pool before maintenance at drainage point | July 98 | Summer | 8.7 | 832 | 84 | 94 | 84 | 36 | 86 | 18 | 0.89 | 210 |
| **4** | Drainage pool far from drainage point before maintenance | July 98 | Summer | 8.1 | 3,176 | 532 | 822 | 200 | 19 | 400 | 45 | 0.85 | 580 |
| **5** | Drainage pool after maintenance far from drainage point | Jan. 99 | Winter | 8.7 | 2,070 | 820 | 1,020 | 168 | 77 | 315 | 25 | 0.78 | 340 |

held the view that a cost-sharing arrangement for minor aspects of well maintenance and irrigation and drainage system O&M would be possible.

- It was felt that government agencies should play the following role:

  - Primary role in system O&M and provision of hardware inputs
  - Replacement and major maintenance of existing wells

  Two engineer respondents were of the view that the government should oversee the work of the user's association.

Based on the above, a work plan was developed to pursue the objective of developing a groundwater stakeholder association. An initial reconnaissance field trip to El-Farafra in March 1999 achieved a consensus among farmers and local leaders to form and formally register Water User Unions and federations as per the provisions of Law 213.

4.5.2 Strategy for Establishment of Groundwater Users Unions in El-Farafra Oasis

With the NVWRDD authorities and local El-Farafra Council leaders, a work plan was developed setting out a strategy for implementing the groundwater user development program. The main features of this organizational strategy stress consultation with farmers and dialogue between farmers and NVWRDD officers.

- In consultation with groundwater using farmers, NVWRDD officials, and local leaders, identify main problems and priorities regarding irrigation, drainage, and agricultural production.
- Identify initial set of well-water command areas on which to establish the first WUUs.
- Prepare list of WUU roles and responsibilities.
- Multiple meetings with all farmers on the selected wells to assess the land served by the wells and the condition of the mesqas.
- Conduct a series of meetings among the farmers on each well to orient them to WUU formation concepts and responsibilities, and to arrive at a consensus regarding WUU objectives.
- In collaboration with farmers and NVWRDD officials, draft WUU charter documents.
- First meeting of WUU General Assembly is held, at which time the Executive Council is elected from among the general membership.
- The WUU Executive Council selects its board of officers, *i.e.*, Chairman, Treasurer, and Secretary, from among its members.
- Orientation Training Sessions for irrigation engineers and technicians and WUU Executive Council on respective responsibilities and roles of each set of stakeholders.
- NVWRDD to issue formal registration documents and certification to WUU, assigning a formal registration number. Chairman of WUU to retain copies of all formal certificates and documents.
- Inauguration ceremony to be held with all stakeholders once Law 213 registration formalities are completed.
- Organize and register an initial 3 WUUs in West Qasr El-Farafra, and continue with an additional 4 organizations.
- Establish WUU federations in West Qasr El-Farafra based on clustered well WUUs.

- Following formation of WUU Federations throughout the Oasis areas of El-Nahda, Sheikh Marzouk, and Abu-Minqar, a Water Board encompassing all WUU federations may be formed under the provisions of Law 213.

### 4.5.3 Implementation Activities Undertaken

The documents contained in Appendix B of this report detail the process whereby the WUUs were organized and officially registered. In each of the three WUUs that have been organized, the phased implementation schedule was adhered to.

A consultant experienced in organizing farmers into water user associations was engaged by EPIQ to assist in the process of organizing farmers in the El-Farafra area and the formation of WUUs. During initial consultations and field visits, general information was collected on land ownership patterns in the El-Farafra oasis region and in the selected program area. Options for organizational structure were reviewed, following which consensus was reached to develop associations having legal foundation under the aegis of Law 213. This resulted in a collective decision to form Water User Unions, demarcated on a water-source basis (i.e. one or more wells), with higher level apex organizations (i.e. federations) formed of WUU clusters, and the entire command area to be covered by an area water board. Further, it was decided to initiate the work in an agricultural area owned and operated by graduates, moving on to other areas at a later date.

This decision was taken in consideration of the recent establishment of the NVWRDD in El-Farafra and the relative inexperience and junior status of most of the staff positioned there.

Multiple meetings of interested farmers were held at the outset in order for the public to understand the concepts and implications of the well user's organizing process. Meeting topics included benefits and costs to farmers related to establishment of WUUs in the area and roles and responsibilities of farmers to make them viable entities. Farmers understood the advantage of being able to collectively address common problems related to water delivery, timing of well closure and operation, haphazard maintenance of the channels, *etc*. Many of the common problems are best addressed through WUUs, as the conglomerate of farmers allows the NVWRDD to deal with relevant issues more effectively. Farmers understood that the objective is not only to register complaints but also to work together with officials and technicians. It was decided that a single WUU covering the entire 12-well area would be too large to manage efficiently. The hydrological boundaries of each WUU were discussed with farmers and NVWRDD officials prior to the start of implementation.

Between March and May 1999, the organizing strategy was implemented on three well sites, and three WUUs were formed and officially registered. These WUUs are located at Wells No. 7, 16 and 18. Participatory rural appraisal, collection of data on cropping patterns and production, and assessment of WUU internal resource structure, were elements in the WUU organizational process. Each WUU general assembly elected its Executive Council members with its panel of officers. The officers were given an orientation of duties, roles and responsibilities. The WUUs decided that its members would participate with the NVWRDD engineers in command area mapping.

Upon successful completion of the WUU organizing process, the NVWRDD authorities in Kharga issued official certificates, testimony that the WUUs are recognized by the government as legitimate entities with all the rights and privileges under the previsions set forth in Law 213. A ceremony was held May 13, 1999, wherein the registration certificates were formally handed over to the leaders of the new WUUs.

In view of the popular interest among the El-Farafra farming community in forming WUUs, a decision was made by the civil authorities and MPWWR to continue formation of WUUs on the remaining well sites in the command area of West Qasr El-Farafra. These are wells numbered 11, 14, 15, 19, 20 and 21. Wells 11 and 15 will be combined as one WUU. It is expected that this process will continue through June 1999, following which efforts will be made to organize a water user federation for that entire command area in July 1999.

## 4.6 Public Awareness

### 4.6.1 Need

It is evident from the qualitative research undertaken to date that a campaign to raise public awareness of groundwater resource management issues is critically needed. The El-Farafra Focus Group Workshop Report (Appendix C) indicates that:

- Although 87.5% of farmers agree that groundwater in El-Farafra Oasis is being lost or wasted, 71.9% do not think water is scarce in the oasis.

- Although 90% of farmers recognize that the free-flowing condition of wells will eventually stop and pumping will be required, over half (63.3%) are not aware that groundwater is finite.

If water users do not accept that their groundwater supply is limited, they will not be prepared to adopt new practices related to water conservation. Behavior change is a complex and gradual process. Typically, individuals or communities advance through a series of five distinct steps: awareness, persuasion, decision, adoption, and confirmation. Before farmers will regularly practice water conservation, they need to be aware that the groundwater resources are finite and convinced that changes in their behavior will indeed make a difference.

Based upon the EPIQ team's success in establishing WUUs at three well sites to date, it appears that willingness to join WUUs is quite high. This is also supported by the El-Farafra Focus Group Workshop Report, which says that 82% of the respondents agreed that establishing a union of water users to assume some operation, maintenance and management responsibilities for the free-flowing groundwater was feasible. The report also indicates that respondents understood the role of WUUs.

However, registration of WUUs is only the beginning. As the farming community of El-Farafra is not homogenous, but made-up of several distinct groups (indigenous residents, recent immigrants, large investors and young graduates), developing and maintaining cooperative relations within and between WUUs may pose a significant challenge.

### 4.6.2 Communication Strategy

To support the policy initiatives underway in El-Farafra Oasis, the communication strategy needs to encompass the following two campaign themes:

- Increase awareness that the groundwater resource is limited and finite
- Promote farmer participation and cooperation in WUUs

### 4.6.3 Campaign Objectives

Although the objectives for both campaign themes support the overall communication strategy, for clarity they can be organized as follows:

- Increase awareness that the groundwater resource is limited and finite

  - Increase knowledge regarding water conservation practices.
  - Instill the idea that every water user can make a difference.
  - Increase the adoption of water conservation practices: implementation of new irrigation techniques, selecting crops/varieties with reduced water requirements, keeping water channels free of aquatic plants or debris, increasing use of drainage water, increasing water storage capacity, and irrigating at night.
  - Reduce/eliminate tampering with wellheads.

- Promote farmer participation in WUUs

  - Increase understanding of what a WUU is, how it functions, the benefit to the farmer, community and the Irrigation Authority.
  - Increase awareness that groundwater is a shared resource, not only among neighbors in El-Farafra, but also with other oasis communities as well as other countries.
  - Increase willingness to work together for the common good.
  - Increase willingness to cooperate with other WUUs and governmental authorities in the oasis.
  - Emphasize benefits of the WUU to farmers and other groups.

Although irrigation at night is listed above as a practice to be promoted among farmers in El-Farafra, it requires further examination. According to the El-Farafra Focus Group Workshop Report, only 17 of 32 farmers irrigate at night, although almost all felt this would help solve water distribution problems. On a recent trip to El-Farafra, Eng. Dina of the Water Communication Unit asked farmers why they did not irrigate at night. The following two factors were reported: 1) farmers were reluctant to travel (for a second time each day) the long distance to their fields and back, and 2) they were fearful of snakes and scorpions on route. These resistance factors are, based upon personal safety and inconvenience. But the Focus Group Workshop Report also indicates that Farmer's have strong views about the need to "better control the free-flowing wells" (weighted average rank of importance 2.81). This view, combined with the resistance factors mentioned above, suggests that a campaign encouraging night irrigation would stand little chance of success, unless or until the farmers' livelihoods depended upon it. Policy makers should therefore not rely on awareness to increase night irrigation significantly, but should seek to implement a technical solution if possible.

### 4.6.4 Audiences

The primary target audience for both campaign themes is farmers in El-Farafra Oasis. Despite differences in characteristics of El-Farafra farmers, further segmentation would not be feasible or advisable at this stage.

Other audience groups include:

- School children of El-Farafra Oasis
- Non-farming adults of El-Farafra Oasis
- Policy and decision makers

Increasing knowledge of the water situation in the Oasis and what can be done to protect this valuable resource, and increasing willingness to participate in conservation measures among school children and the non-farm community is vital to the long-term success of the policy initiatives. The children of today will become the farmers of tomorrow. Children can also carry or read messages to their parents. To protect the finite water resources of the oasis, the groundwater aquifer must become an important concern for the entire community, not only farmers.

As schools are few in the area, developing materials for school children to take home would be an appropriate way to disseminate information. We need to confirm the number, level/type, approximate size, and locations of the schools in El-Farafra Oasis.

Materials developed for use within the communities of El-Farafra Oasis also need to be distributed among policy and decision-makers in Cairo and at the district level. This audience must also be made aware of the finite nature of the aquifer and what can be done to conserve the valuable resource, in order to ensure that policies and regulations affecting the region are appropriate. This group is also an important audience because they can either advance or deter development and dissemination of campaign messages at the local level.

If messages are applicable beyond the current pilot area, materials should be developed to allow for usage in the other Oases of the Western Desert and even nationally.

### 4.6.5 Proposed Initial Campaign Deliverables and Distribution by Target Audience

#### *4.6.5.1 For Farmers:*

- Design and print three posters
    - Message 1: Water is limited and finite
    - Message 2: What you can do to make a difference
    - Message 3: Participate in a WUU: working together we all benefit
- Develop and print flyer outlining what a farmer can do to conserve water
- Install signage at each wellhead site to discourage any tampering

#### *4.6.5.2 For School Children:*

- Design a wall chart showing formation of the aquifer, supply and demand, other oasis and countries sharing the aquifer

- Develop booklet (text and activities) that describes formation of the aquifer, supply and demand, what children can do, what farmers can do, water logging/drainage problems and solutions, *etc*.

#### *4.6.5.3 For Policy and Decision Makers:*

- Develop and print fact sheet on WUUs
- Develop and print fact sheet on free-flowing groundwater resource and management
- Produce 15-minute documentary on WUUs
- Produce 15-minute documentary on free-flowing groundwater resource and management

All the materials listed in this section may be distributed or used with more than one audience, as well as in other areas of the Western Desert or, in the case of WUU materials, potentially throughout the country.

GreenCOM and the Water Communication unit are exploring the possibility of commissioning the well-known artist Badr Abdel Moghny Aly from El-Farafra to do the artwork for the print materials listed above. Badr Abdel Moghny Aly has built his own studio and gallery in the town of El-Farafra. He has won numerous awards and shows his work nationally.

### 4.6.6 Sources of Information

In the Focus Group Workshop, 29 of 31 respondents obtained information from TV and radio, while 14 reported reading the newspaper. This suggests that broadcast media would be the most successful channel of communication. However, currently there is no regional TV channel or local radio station serving the Western desert. Furthermore, free-airing of regional public service announcements on national TV, and radio broadcasting with adequate frequency, is unlikely. Therefore, this campaign strategy focuses on print materials that can be used/distributed through WUUs, schools, agricultural cooperatives, the irrigation authority and other local meetings or gathering places. However, we do need to confirm which TV and radio channels are received in the Oasis, as airing of the 15-minute documentary on Free-Flowing Groundwater Resource and Management, for example, may be possible. In addition, imbedding local images or messages in the national campaign efforts may be possible.

## 4.7 Economic Considerations

### 4.7.1 Economic Analysis

Groundwater is a common resource, even when pumped. Without management of the whole groundwater resource, there is no incentive to conserve water on the part of users, since any water conserved by one user can be accessed by another. The resource is likely to be overused because those who extract the water do not have to consider other users. Unless the managing entity takes into account the entire aquifer, management will be suboptimal.

Management of the entire Nubia Sandstone Aquifer underlying parts of four separate African countries is currently impossible. But applying uniform and consistent management policies over the part of the aquifer supplying water to the Western Desert oases of Egypt is not only possible but essential. Thus, policy recommendations should be based on consistent and uniform water conservation measures for management of the groundwater basin of the Western Desert.

The proposed plan consists of reducing the well discharge to a flow sufficient to meet the crop irrigation requirements of the command area without exceding the design future pumping rate. This action will have two effects: first, it will reduce the amount of water in the drains, and second it will lengthen the effective life of the free-flowing water. The latter is true only if the policy is applied throughout the aquifer, permitting a delay in the time at which wells must be converted to pumping. However, the reduction of flow from the 10 wells of the West Qasr El-Farafra area (or any other local area) alone will not significantly increase the life of the free-flowing conditions over the whole aquifer. Thus, the program of policy change must apply to all of the New Valley.

Estimates from the various documents available suggest that with an extraction rate based on the planned development, all wells will have to be pumped in about 2030. However, if the current continuous free-flowing discharge rates persist, it is expected that all wells will have to be pumped no later than 2015. Thus, by controlling the free-flowing wells to meet only the required water demands, pumping costs can be postponed by about 15 years for the lowest elevation (highest piezometric head) wells.

There is, of course, some temporal trend across the aquifer, as the wells on higher ground cease flowing and the piezometric head decreases in the free-flowing wells. The exact nature of this trend is unknown and probably nonlinear. If a linear relationship is assumed, the free-flowing condition will be extended by about 7.5 years for the average well.

Pumping costs are estimated to be LE 0.10 per cum (WRSR Report #18). This value is also an average over the pumping depth. Pumping costs, too, change as piezometric head decreases. The average planned extraction from wells after pumping is required is 8,000 cum per day for 300 days per year. Thus, the average annual cost of pumping per well is LE 240,000. Avoiding that cost over a 7.5-year extension of the free-flowing condition has a present value of LE 1.15 million (using a 12% discount rate). For the average well, this extension begins in about 2008. The present value of this "savings" is slightly more than LE 463,000 per well. If the average well serves 300 feddans, the average present value is about LE 1,540 per feddans.

There are many assumptions made in this analysis. Still, the results indicate the large losses incurred by allowing free flowing conditions in excess of actual irrigation demands. This brief economic analysis illustrates a significant benefit for controlling free-flowing well discharges to match crop irrigation requirements.

An alternative approach would be to let the free flowing wells continue to flow, but to develop the land at an accelerated pace to take advantage of the excess water flow, aiming at full "official" development (31,000 feddans) within 3-5 years. According to local MALR officials, there are currently about 10,000 cultivated (producing) feddans in the "official" area. That leaves about 21,000 feddans to be developed. The current planned rate of development is about 1,500 feddans per year over 15 years. The faster buildout would result in a rate of 4,200 feddans per year over five years.

The net return per feddan in the area appears to be about LE 2,000 (including return to land). The present value of accelerated development would be the difference in net returns between the profit generated from current development rates in the official areas and that of the fast buildout. The present value (at a 12% discount rate) of the difference between present and proposed buildout is LE 105 million, or LE 3,418 per feddans (over all 31,000 feddans). Thus, this alternative appears to be economically preferred to reducing flows.

However, the lack of development on the command areas suggests that barriers to fast development exist. While a full list of disincentives has not been determined, initial investments may be an obstical due to a lack of long term capital availability and the fact that land titles are not immediately available. At the very least, some subsidies appear to be necessary. Moreover, as development in the command area increases, the capital invested by unofficial farmers (currently about 8,000 feddans) who will not continue to have access to water will be stranded. That economic and political cost may be high.

#### 4.7.2 Aids/Incentives

Information was gathered from the local PBDAC office and the MALR extension office regarding the availability of agricultural services to local farmers. All services currently available to the general farming population are available in El-Farafra. Seeds, fertilizers and other inputs are available from both GOE and private sources.

Credit is available from the PBDAC for short-term operation loans, for those who possess a Hiaza card. Only farmers in the command areas are issued these cards. The local unofficial irrigators cannot obtain credit without either access to a Hiaza card or with the support of someone who has a card. Moreover, medium-terms loans, such as might be necessary for well maintenance, are not easily obtained. Some loans have been granted for well rehabilitation and maintenance, according to the local PBDAC representative. Long-term loans are not generally available, due to the lack of tangible collateral (mainly land ownership registration).

There are currently no economic incentives to conserve water. Most farmers on official lands have gravity flow irrigation, so that they incur no pumping costs. Moreover, since the groundwater resource is a common property, there is an incentive to use the water as fast as possible. Unofficial irrigators generally pump from drains or other spills, which provides some cost incentive to conserve. But for farmers in the command area, that incentive is absent until the piezometric head declines sufficiently to force pumping. Even then, there is incentive to overuse. In fact, the farmers themselves do not control the flow rates of the wells, so even a water charge would not change these flows.

Individual farmers also have little reason to participate in well maintenance, firstly because the GOE has historically provided it, and secondly because the well itself is a common property among those it serves. WUUs charged with the responsibility for maintenance might be more effective. The incentive to take over those responsibilities is low so long as water is available from the GOE in more than adequate quantities and at no cost.

# 5 POLICIES AND PROCEDURES FOR FREE-FLOWING GROUNDWATER MANAGEMENT

## 5.1 Policies

Based upon considerations in the foregoing sections of this report the Deep Groundwater Work Group selected the following list of policies as recommendations for adoption by the MPWWR. Each numbered statement is a recommended policy. Policies #1, #2, #4, #5, and #6 were developed from possible policies of Section 4.4. They were fully discussed in that section and discussion will not be repeated here. See the Executive Summary for brief discussion and justification. Immediately following the statements of policies #3 and #7 are brief comments on justification for selecting these two policies.

8. Free-flowing well discharge will be adjusted monthly to match crop irrigation requirements within the command area of each particular well, with the maximum discharge not exceeding the well's design future pumping rate.

2. For free-flowing wells, nighttime well flow will be stored on the land surface, either in the existing canals or new storage facilities, and daytime well flow will be controlled.

3. The MPWWR will establish a program of continuous groundwater monitoring for all wells (public and private).

Policy #3 is needed to provide a complete and continuous base of reliable data for managing the groundwater resources for which the Ministry has responsibility. In the future, such an historical database will allow assessment of the success of any policy changes implemented. Results can be used to determine the necessity of any future corrections to policy. The database is needed whenever groundwater models are used as management tools. In areas allocated for large scale private sector irrigated agriculture projects, the private sector will be required to establish monitoring well networks in accordance with the MPWWR technical guidelines. MPWWR staff must be allowed to periodically monitor these wells to get the required data.

4. Operating criteria will be defined for transition from free-flowing to pumped conditions of the wells.

5. The MPWWR will continue the program for establishment of water user organizations in accordance with Law #213.

6. No growth of unofficial irrigation will be allowed.

7. A working group will be established with membership from MPWWR, MALR, and MHNC, chaired by the representative of MPWWR, to provide continuing review of issues/conditions and policies for managing the groundwater resources in the Western Desert.

   Several issues/conditions and policies for managing the groundwater resources in the Western Desert will need continuing attention. Two examples are: (a) transition from free-flowing to pumped wells (See policy #4), and (b) unofficial irrigation that currently exists on about 10,000 feddanss in El-Farafra – Abou-Minqar. Such issues/conditions and policies may best be handled by a working group of representatives of all ministries involved.

## 5.2 Procedures for Policy Implementation

Some of the possible policies listed in Section 4.4 are procedures rather than policies. These procedures are considered necessary for complete implementation of the policies listed in Section 5.1. Most procedures of the following list were adequately discussed in Section 4.4 and discussion will not be repeated here. Others have brief explanations following the statement of procedure.

A. Before the beginning of each growing season, the WUU for each well (or wells) will provide to the NVWRDD the total areas of each crop to be grown that season.

These data will form the basis upon which the water delivery schedule is to be determined.

B. Personnel of the NVWRDD will determine the water delivery schedule for each month of each season and provide results to the leader of the WUU.

Using the cropping data from the WUU, the crop water requirements for the particular season, and proper values of irrigation efficiency for the given area, the NVWRDD will determine the required amount of water needed for the peak irrigation month. If this value is less than or equal to the available monthly design discharge of the well, the water delivery schedule for each month will be determined and delivered to the WUU chairman.

If the water needed for the peak irrigation month exceeds the available monthly design discharge, then several different crop distributions will be used to balance the available supply with crop needs. Several different alternative crop distributions that balance available supply with demand will be developed. These alternative crop distributions will be provided to the WUU and they will decide what changes they will make in their original cropping plans for the season to balance supply with demand. This new cropping pattern that balances supply and demand will then be used to determine the water delivery schedule for the season.

C. With storage of nighttime flow, the free-flowing well discharge rate will be set by NVWRDD personnel to deliver (in 24 hours) the volume of water needed for each day's irrigation. The well discharge will be changed only once each month as per policy #1.

D. Close contacts and coordination between the MPWWR (NVWRDD), MALR (NVAD), and WUUs will be needed to solve irrigation problems and to develop the water delivery schedule each season.

E. Groundwater extraction zones of future wells will be distributed among different depth zones of the aquifer over the reclaimed area.

   There is evidence from geohydrological studies and field experience in the Western Desert to support following this procedure. This procedure should reduce the future rate of decline of aquifer piezometric levels and prolong the period of free-flowing conditions in the area and hence the time to when pumping of wells must begin. There is considerable evidence that while the Nubia Sandstone Aquifer acts regionally as a single unit, locally it consists of several depth zones that are somewhat separated. The EPIQ Report #10 gives details on this aspect of this aquifer tapped by the free-flowing wells. Further evidence is provided by the fact that when certain wells have ceased to function in the free-flowing condition, replacement wells, located nearby and drilled to a deeper depth, have produced free-flowing conditions.

F. The MPWWR, through the RIGW, will conduct a research and demonstration study of the use of remotely actuated automatic slow-closing valves for flow regulation (and/or possible future nighttime closure) of the free-flowing wells.

G. A periodic maintenance program for all irrigation water facilities will be established to provide compatible utilization, conservation, and preservation of the groundwater resources over the planned period of groundwater mining in the Western Desert.

H. The MPWWR and MALR will jointly conduct a review of contract compliance within the well command areas to determine if contract stipulations have been met by the landholders pursuant to Law #143 of 1981. If violations exist that will make these lands available to new farmers, the lands should be reallocated to ensure that all land within the command area is fully utilized.

I. The NVWRDD needs to be strengthened and adequately budgeted for the number of trained technical personnel in each required specialization and for the equipment and measuring devices necessary for performing its roles and responsibilities.

J. The MPWWR, through the Water Communication Unit, will establish an ongoing educational program, for all stakeholders and the public, on water resource issues affecting free-flowing groundwater management in the Western Desert.

# 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

Based upon the work reported herein, it is concluded that the policies and procedures of Section 5 will help to reduce water wastage and extend the life of the free-flowing groundwater resource from the Nubia Sandstone Aquifer of the Western Desert. It is realized that in the Siwa Oasis, completely closing the well valves will not prevent water loss because of the well construction and the highly fractured nature of the limestone aquifer. It is recognized that West Qasr El-Farafra does not have conditions exactly the same as all areas of the Western Desert, but neither does any other local area that may have been selected. This area was small enough to obtain useful data and make field observations from which the policies and procedures could be developed. It is concluded that the study area was large enough and representative enough of reclaimed areas in general to provide reasonable assessment of the likely success of the policies and procedures.

It is further concluded that Benchmark C.2 and its two verification indicators have been achieved. These two verification indicators are:

1. MPWWR will approve a policy package for free-flowing groundwater in reclaimed areas.
2. Initiate the formation of a groundwater user association in a selected reclaimed area in the Western Desert.

The first indicator was achieved with preparation of this report and the recommended policy package contained herein for which approval is expected following the workshop held on June 11-12, 1999.

The second indicator was achieved on May 13, 1999, when formal certificates were presented to officers of three new Water User Unions formed in the West Qasr El-Farafra area. These are the first ever WUUs formed in the Western Desert in accordance with Law #213.

## 6.2 Recommendations

The MPWWR should:

- Adopt and implement the numbered list of policies given in Section 5.
- Follow the procedures listed in Section 5 in order to implement the policies effectively.

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**Task Order 807**

# *FREE-FLOWING GROUNDWATER MANAGEMENT IN THE WESTERN DESERT*

## *REPORT NO. 16*

Volume II

APPENDICES

June 1999

**Water Policy Program**

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*APPENDIX A*

**INVENTORY OF CULTIVATED CROPS IN EL-FARAFRA OASIS BY SEASON AND RECLAIMED AREA FROM WINTER 1993/94 THROUGH WINTER 1998/99**

**Includes Tables A-1 through A-11   8.**

# APPENDIX A

## INVENTORY OF CULTIVATED CROPS
## IN EL-FARAFRA OASIS
## BY SEASON AND RECLAIMED AREA
## FROM WINTER 1993/94 THROUGH WINTER 1998/99

**Includes Tables A-1 through A-11**

Table (A-1). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1993/94 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Wheat | 105.20 | 1,141.67 | 1,323.50 | 320.00 | 1,227.62 | 744.00 | 4,861.99 |
| Barley | 18.38 | 43.75 | 214.00 | 43.00 | 104.25 | 25.50 | 448.88 |
| Beans | 8.96 | 146.25 | 22.50 | 7.00 | 462.25 | 236.00 | 882.96 |
| Berseem | 30.00 | 30.75 | 35.00 | - | 457.25 | 146.00 | 699.00 |
| Alfalfa | 48.25 | 43.25 | 196.50 | 77.00 | 299.25 | 138.00 | 802.25 |
| Fenu-greek | 3.08 | 91.33 | 76.00 | 1.00 | 132.25 | 19.00 | 322.66 |
| Onion | - | 13.25 | 13.00 | 1.00 | 5.00 | 4.00 | 36.25 |
| Caraway Seeds | - | 6.00 | 4.00 | 25.00 | 6.50 | - | 41.50 |
| Fennel Flower | - | 5.00 | 7.00 | - | - | - | 12.00 |
| Aniseed | - | - | 1.00 | - | 6.00 | - | 7.00 |
| Cumin | 1.00 | - | - | - | 19.50 | - | 20.50 |
| Lupines | - | - | 2.00 | - | 2.00 | - | 4.00 |
| Total Area | 214.87 | 1,521.25 | 1,894.50 | 474.00 | 2,721.87 | 1,312.50 | 8,138.99 |

Table (A-2). Inventory of Cultivated Crops in El-Farafra Oasis in Summer Season, 1994 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Sorghum | 20.83 | 69.29 | 46.5 | 37.0 | 256.0 | - | 429.62 |
| Maize | 2.83 | 24.75 | 61.0 | 4.0 | 98.5 | 72.5 | 263.58 |
| Sesame | 3.33 | 681.75 | 79.0 | 21.0 | 335 | 45.5 | 1,165.58 |
| Sun flower | 0.125 | 115.63 | 17.0 | 8.5 | 277.0 | - | 418.26 |
| Cucumber Seeds | - | 127.25 | 244.5 | 37.5 | 13.5 | 16.0 | 438.75 |
| Peanut | - | - | 11.5 | 1.0 | 3.0 | - | 15.50 |
| Sugarcane | - | 0.63 | - | - | - | 2.0 | 2.63 |
| Rice | 17.0 | 47.75 | 141.5 | 41.5 | 124.0 | 197.0 | 568.75 |
| Lentile | - | 0.08 | 0.29 | 0.08 | 0.38 | - | 0.83 |
| Alfalfa | 48.25 | 48.8 | 282.0 | 80.5 | 299.25 | 164.5 | 923.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vegetables | 1.1 | 46.4 | 95.12 | 16.0 | 49.3 | 25.6 | 233.54 |
| Total Area | 93.49 | 1,162.33 | 978.41 | 247.08 | 1,455.93 | 523.10 | 4,460.34 |

Table (A-3). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1994/95 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Wheat Giza | 38.00 | 374.00 | 2,022.50 | 446.00 | 610.00 | 400.00 | 3,890.5 |
| Wheat Giza | - | 732.00 | 299.50 | 14.00 | 10.00 | 20.00 | 1,075.5 |
| Wheat Baladi | 67.80 | - | 94.50 | - | 580.50 | 213.50 | 956.30 |
| Barley | 13.04 | 82.75 | 50.00 | 182.00 | 56.50 | 43.50 | 427.79 |
| Berseem | 22.96 | 61.08 | 76.00 | 11.50 | 438.08 | 180.50 | 790.12 |
| Alfalfa | 62.42 | 52.63 | 318.50 | 33.00 | 229.75 | 193.00 | 889.30 |
| Beans | 14.71 | 187.21 | 85.50 | 33.00 | 497.25 | 139.00 | 956.67 |
| Fenu-greek | 23.00 | 113.75 | 114.50 | 18.50 | 192.92 | 44.00 | 506.67 |
| Onion | - | 7.58 | 36.50 | 3.75 | - | - | 47.83 |
| Cumin | 1.88 | - | 3.00 | 1.00 | 18.50 | - | 24.38 |
| Fennel | - | 0.50 | - | - | - | - | 0.50 |
| Lupines | - | - | 4.50 | - | - | - | 4.50 |
| Chick peas | - | - | - | - | 2.00 | - | 2.00 |
| Sugarcane | - | 0.63 | - | - | - | 2.00 | 2.63 |
| Carawey | - | 2.00 | - | - | 1.00 | - | 3.00 |
| Lentile | 2.12 | 0.46 | - | - | - | - | 2.58 |
| Peas | 1.63 | 0.75 | 12.00 | 9.00 | - | - | 23.38 |
| Garlic | - | 0.17 | 3.75 | 2.50 | - | - | 6.42 |
| Potatoes | - | - | 3.50 | - | - | 0.50 | 4.00 |
| Tomatoes | 0.33 | 13.83 | 40.00 | 4.00 | 13.25 | 14.00 | 85.41 |
| Egg plant | - | 0.83 | - | - | - | - | 0.83 |
| Gress | - | - | 43.00 | 28.00 | - | - | 71.00 |
| Radish | - | - | - | 6.00 | - | - | 6.00 |
| Green pepper | - | 0.50 | - | - | - | - | 0.50 |
| Common | - | - | - | - | 4.00 | - | 4.00 |
| Total Area | 247.8 | 1,630.67 | 3,207.25 | 792.25 | 2,653.7 | 1,250.00 | 9,781.8 |

Table (A-4). Inventory of Cultivated Crops in El-Farafra Oasis in the Summer Season, 1995 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Sorghum | 29.90 | 111.80 | 57.00 | 15.00 | 254.00 | 25.00 | 492.70 |
| Maize | 7.90 | 94.00 | 72.00 | 40.00 | 248.30 | 86.00 | 548.20 |
| Sesame | 14.50 | 861.40 | 108.80 | 53.50 | 276.00 | 54.00 | 1,368.2 |
| Cucumber | - | 57.50 | 12.00 | 15.00 | 7.00 | 266.00 | 357.50 |
| Sun flower | 0.40 | 108.50 | 41.50 | 28.00 | 448.90 | - | 627.30 |
| Sugarcane | - | 8.00 | - | - | - | 11.50 | 19.50 |
| Peanut | 0.50 | 1.50 | 19.70 | 8.00 | - | - | 29.70 |
| Maize fodder | - | 0.50 | - | - | - | - | 0.50 |
| Soy beans | - | - | - | 1.50 | - | - | 1.50 |
| Alfalfa | 72.40 | 68.30 | 300.00 | 150.00 | 301.30 | 193.00 | 1,085.0 |
| Rice | 3.50 | 102.90 | 571.50 | 200.00 | 298.80 | 176.00 | 1,352.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Vegetables | 0.30 | 44.10 | 158.50 | 45.00 | 68.00 | 70.50 | 386.40 |
| Total Area | 129.0 | 1,458.50 | 1,341.00 | 556.00 | 1,902.3 | 882.00 | 6,268.8 |

Table (A-5). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1995/96 (feddans).

| Crop \ Area | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Wheat | 115.30 | 1,274.80 | 3,177.60 | 1,033.00 | 1,313.50 | 762.00 | 7,676.20 |
| Barley | 22.80 | 102.80 | 102.50 | 808.00 | 75.50 | 76.00 | 1,187.60 |
| Beans | 29.90 | 497.00 | 246.00 | 145.00 | 645.00 | 184.00 | 1,746.90 |
| Fenu greek | 9.80 | 39.00 | 94.00 | 25.00 | 112.00 | 13.00 | 292.80 |
| Lentile | 0.50 | 2.50 | 1.00 | - | - | - | 4.00 |
| Onion | - | 60.50 | 127.60 | 34.50 | 10.80 | - | 233.40 |
| Berseem | 36.60 | 115.00 | 33.50 | - | 393.00 | 220.00 | 798.10 |
| Lupines | - | 0.50 | - | - | - | - | 0.50 |
| Fennel Flower | - | 0.30 | - | - | - | - | 0.30 |
| Chick peas | _ | 1.50 | - | - | - | - | 1.50 |
| Cumin | - | - | 4.00 | 5.00 | 5.30 | - | 14.30 |
| Caraway Seeds | - | - | 4.00 | 5.00 | - | - | 9.00 |
| Aromatic plants | - | - | - | - | 2.00 | - | 2.00 |
| Sugarcane | - | 8.40 | - | - | - | 13.50 | 21.90 |
| Alfalfa | 130.80 | 68.90 | 253.30 | 54.00 | 202.80 | 225.00 | 934.80 |
| Coriander | - | - | - | 5.00 | - | - | 5.00 |
| Aniseeds | - | - | - | 8.00 | - | - | 8.00 |
| Parsley | - | - | - | 5.00 | - | - | 5.00 |
| Peas | 3.30 | 3.80 | 9.00 | 1.00 | - | - | 17.10 |
| Common beans | - | 1.00 | - | 1.00 | - | - | 2.00 |
| Potatoes | - | - | - | 0.50 | - | - | 0.50 |
| Cress | - | - | 9.50 | 39.50 | 2.50 | - | 51.50 |
| Tomatoes | - | 4.20 | 89.00 | 12.00 | 14.00 | 17.50 | 136.70 |
| Garlic | - | - | 5.50 | - | 4.50 | - | 10.00 |
| Total Area | 349.00 | 2,180.20 | 4,156.50 | 2,181.50 | 2,780.90 | 1,511.00 | 13,159.10 |

Table (A-6). Inventory of Cultivated Crops in El-Farafra Oasis in the Summer Season, 1996 (feddans).

| Crop | Area |
|---|---|
| Sorghum | 450.04 |
| Maize | 1.226.20 |
| Sesame | 2.048.90 |
| Sun flower | 636.50 |

| | |
|---|---|
| Sugarcane | 71.40 |
| Peanut | 5.00 |
| Maize fodder | 384.00 |
| Soy beans | 3.00 |
| Alfalfa | 1,093.40 |
| Rice | 1,748.70 |
| Vegetables | 496.10 |
| Cotton | 19.25 |
| Seeds | 892.30 |
| Orchards | 499.00 |
| Total Area | 9,574.15 |

Table (A-7). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1996/97 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Wheat | 257.10 | 1,591.30 | 3,952.10 | 1,884.80 | 1,554.7 | 866.00 | 10,106.0 |
| Barley | 50.00 | 74.30 | 77.50 | 80.50 | 41.50 | 67.50 | 391.30 |
| Beans | 42.50 | 442.50 | 480.20 | 213.50 | 614.40 | 229.50 | 2.022.60 |
| Berseem | 37.40 | 149.30 | 58.00 | 4.50 | 359.40 | 190.00 | 798.60 |
| Fenu greek | 7.80 | - | 80.00 | 18.50 | 10.30 | 4.00 | 120.60 |
| Onion | - | 3.50 | 74.30 | 34.00 | 5.00 | - | 116.80 |
| Lentile | 1.30 | - | 7.50 | 1.00 | 1.50 | - | 11.30 |
| Sugarcane | - | 43.30 | 15.00 | - | 5.00 | 12.00 | 75.30 |
| Fodder peats | - | - | 2.00 | - | - | - | 2.00 |
| Alfalfa | 154.30 | 92.00 | 252.50 | 41.00 | 282.60 | 190.00 | 1,012.40 |
| Tomatoes | - | 4.10 | 72.50 | 70.00 | 1.00 | 5.50 | 153.10 |
| Garlic | - | - | 3.00 | 3.50 | - | - | 6.50 |
| Peas | 2.90 | 1.80 | - | 1.00 | - | - | 5.70 |
| Green pebbles | - | - | 8.50 | - | - | - | 8.50 |
| Egg plant | - | - | 7.50 | - | - | - | 7.50 |
| Gress | - | - | - | 7.00 | - | - | 7.00 |
| Potatoes | - | - | - | 0.30 | - | - | 0.30 |
| Cumin | - | 0.40 | 8.00 | - | 2.00 | - | 10.40 |
| Aniseeds | - | - | 1.00 | - | - | - | 1.00 |
| Coriander | - | - | 1.00 | - | - | - | 1.00 |
| Aromatic | - | 4.00 | 10.00 | - | - | - | 14.00 |
| Cockle | - | 0.30 | - | - | - | - | 0.30 |
| Carawy seeds | - | 5.50 | 2.00 | - | - | - | 7.50 |
| Total Area | 553.30 | 2,412.30 | 5,112.60 | 2,359.60 | 2,877.4 | 1,564.50 | 14,879.7 |

Table (A-8). Inventory of Cultivated Crops in El-Farafra Oasis in the Summer Season, 1997 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Cotton | - | 4.50 | 10.20 | - | 39.50 | - | 54.20 |
| Sorghum | 42.40 | 511.00 | 107.30 | 102.00 | 244.00 | - | 1,006.70 |
| Maize | 45.30 | 146.00 | 429.30 | 239.50 | 466.60 | 107.50 | 1,434.20 |
| Sun flower | - | 54.50 | 9.00 | 96.50 | 87.20 | - | 247.20 |
| Cucumber | 20.50 | 177.50 | 1,428.0 | 1,073.00 | 9.00 | 17.00 | 2,725.00 |
| Sesame | 30.00 | 451.00 | 975.50 | 477.00 | 66.30 | 62.00 | 2,061.80 |
| Rice | 23.80 | 403.00 | 608.00 | 142.50 | 772.00 | - | 1,949.30 |
| Soy beans | - | - | 25.00 | - | 12.00 | - | 37.00 |
| Peanut | - | - | 5.00 | 15.00 | - | - | 20.00 |
| Melon | 14.50 | 1.60 | 60.80 | 4.50 | - | - | 81.40 |
| Water Melon | 4.90 | 9.80 | 129.50 | 81.50 | 3.50 | 9.00 | 238.20 |
| Green pebber | - | - | 10.50 | 7.00 | - | - | 17.50 |
| Egg plant | - | - | 10.00 | 7.00 | - | - | 17.00 |
| Tomatoes | - | 18.10 | 29.00 | 45.00 | 1.00 | 10.00 | 103.10 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cow peas | - | - | 14.50 | 7.00 | - | - | 21.50 |
| Common peas | - | - | 6.00 | - | - | - | 6.00 |
| Jew's Malow | - | 3.10 | - | - | - | - | 3.10 |
| Cucumbers | - | 0.80 | 2.50 | - | - | - | 3.30 |
| Squash | - | - | 2.50 | 2.00 | - | - | 4.50 |
| Fooders | 154.30 | 110.60 | 351.60 | 107.00 | 169.00 | - | 892.50 |
| Total Area | 335.70 | 1,891.50 | 4,214.2 | 2,406.50 | 1,870.1 | 205.50 | 10,923.5 |

Table (A-9). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1997/98 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Wheat | 578.10 | 1,570.00 | 5,544.00 | 3,583.50 | 1,779.7 | 575.50 | 13,630.8 |
| Barley | 71.60 | 289.00 | 363.00 | 185.00 | 43.80 | 45.00 | 997.40 |
| Beans | 72.00 | 759.70 | 1,201.90 | 618.70 | 729.10 | 396.30 | 3,777.70 |
| Berseem | 75.30 | 208.60 | 65.00 | 5.00 | 532.30 | 137.30 | 1,023.50 |
| Fenu greek | 4.50 | 4.90 | 56.80 | 27.00 | 17.00 | - | 110.20 |
| Onion | 6.50 | 39.00 | 117.40 | 97.00 | 12.50 | - | 272.40 |
| Lentile | - | - | 7.00 | - | - | - | 7.00 |
| Sugarcane | - | 33.80 | 16.00 | - | 4.00 | - | 53.80 |
| Alfalfa | 16.50 | 98.80 | 278.50 | 70.00 | 125.70 | 184.00 | 773.50 |
| Cumin | - | '- | 12.50 | 7.50 | 0.50 | - | 20.50 |
| Coriander | - | 1.00 | 4.00 | - | - | - | 5.00 |
| Aromatic | - | - | 14.00 | - | 1.00 | - | 15.00 |
| Vegetables | 3.60 | 17.40 | 283.40 | 72.00 | 19.00 | 30.70 | 426.10 |
| Caraway seeds | - | 8.50 | 5.50 | 1.00 | - | - | 15.00 |
| Total Area | 828.10 | 3,030.70 | 7,969.00 | 4,666.70 | 3,264.6 | 1,368.80 | 21,127.9 |

* Includes an area of 9,479 feddans unofficially irrigated, of which 1,571 are in West Qasr El-

Table (A-10). Inventory of Cultivated Crops in El-Farafra Oasis in the Summer Season, 1998 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Total |
|---|---|---|---|---|---|---|---|
| Cotton | 0.50 | - | 61.70 | 19.00 | 70.30 | - | 151.50 |
| Sorghum | 48.80 | 212.00 | 119.50 | 39.50 | 144.30 | - | 564.10 |
| Maize | 45.90 | 97.50 | 527.50 | 46.00 | 129.50 | 77.00 | 923.40 |
| Rice | 81.10 | 978.90 | 1,045.0 | 281.50 | 849.10 | 181.00 | 3,416.60 |
| Sun flower | 5.00 | 22.50 | 102.00 | 39.00 | 177.70 | - | 346.20 |
| Cucumber | 133.60 | 85.50 | 1,154.4 | 644.50 | - | 27.00 | 2,045.00 |
| Sesame | 9.00 | 45.80 | 829.80 | 529.50 | 11.50 | 25.00 | 1,450.60 |
| Alfalfa | 163.50 | 89.50 | 444.00 | 71.50 | 215.00 | 129.50 | 1,113.00 |
| Sugarcane | - | 22.80 | 16.50 | - | 1.00 | - | 40.30 |
| Peanut | - | - | 5.30 | 12.00 | - | - | 17.30 |
| Soy beans | - | - | 13.00 | - | 1.30 | - | 14.30 |
| Tomatoes | 1.50 | 2.00 | 54.50 | - | 1.00 | 9.50 | 68.50 |
| Water melon | 2.50 | 1.00 | 72.30 | 17.00 | 20.80 | 2.00 | 115.60 |
| Melon | 3.50 | 2.80 | 45.50 | - | 11.50 | 4.00 | 67.30 |
| Okra | - | - | 1.30 | 2.00 | - | - | 3.30 |
| Squash | - | - | 19.50 | 9.00 | - | - | 28.50 |
| Egg plant | - | - | 7.30 | 1.00 | - | - | 8.30 |
| Green Pepper | - | 0.80 | 0.50 | - | - | - | 1.30 |
| Cucumbers | - | 1.50 | 12.10 | - | - | - | 13.60 |
| Fooders | - | 56.80 | 62.30 | - | 407.20 | - | 526.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total Area | 494.90 | 1,619.40* | 4,594.0 | 1,711.50 | 2,040.2 | 455.00 | 10,915.0 |

+ 200 feddans of watermelon cultivated in Qarawein and W. El-Henes plains
* Includes 365 feddans, unofficially irrigated outside the command area.

Table (A-11). Inventory of Cultivated Crops in El-Farafra Oasis in the Winter Season, 1998/99 (feddans).

| Area / Crop | Qasr El-Farafra | General Sobeih (West Qasr El-Farafra) | El-Kifah (Sheikh Marzuk) | Abu Horeirah (Sheikh Marzuk) | El-Nahda | Abu-Minqar | Karawein Plain | Total |
|---|---|---|---|---|---|---|---|---|
| Wheat | 406.08 | 1,461.00 | 4,210.67 | 2,771.00 | 1,608.33 | 613.00 | 2.00 | 11072.08 |
| Barley | 45.00 | 220.83 | 333.75 | 310.00 | 56.33 | 33.00 | 8.00 | 1006.91 |
| Beans | 56.21 | 490.50 | 907.00 | 596.00 | 637.08 | 314.00 | - | 3000.79 |
| Berseem | 84.00 | 279.33 | 133.33 | 10.50 | 506.29 | 195.50 | - | 1208.95 |
| Fenu greek | 5.25 | 9.50 | 82.67 | 7.00 | 50.17 | - | - | 154.59 |
| Onion | 3.50 | 28.33 | 63.50 | 186.25 | 10.75 | - | - | 292.33 |
| Lentile | 1.00 | - | 2.17 | - | - | - | - | 3.17 |
| Cotton | - | - | - | 0.50 | - | - | - | 0.50 |
| Alfalfa | 164.21 | 87.50 | 300.17 | 124.00 | 248.25 | 214.00 | - | 1138.13 |
| Tomatoes | - | 2.00 | 78.50 | 20.00 | 11.75 | 31.00 | - | 143.25 |
| Garlic | 5.00 | 2.38 | 9.25 | 9.00 | - | - | - | 25.63 |
| Peas | 2.08 | 4.50 | 43.25 | - | - | - | - | 49.83 |
| Check beans | - | 2.00 | 7.00 | - | 5.50 | - | - | 14.50 |
| Egg plant | - | - | 5.00 | 1.75 | - | - | - | 6.75 |
| Gress | 14.00 | 19.50 | 782.75 | 215.33 | - | - | - | 1031.58 |
| Potatoes | - | - | 3.92 | 1.83 | - | - | - | 5.75 |
| Cumin | - | 5.00 | 7.50 | 3.00 | 4.00 | - | - | 19.50 |
| Aniseeds | - | - | - | - | 1.00 | - | - | 1.00 |
| Coriander | 7.50 | 0.75 | 1.00 | - | 3.00 | - | - | 12.25 |
| Aromatic plants | - | - | 7.50 | - | - | - | - | 7.50 |
| Radish | - | - | 5.00 | - | - | - | - | 5.00 |
| Carrots | - | - | 1.00 | - | - | - | - | 1.00 |
| Sugarcane | - | 20.25 | 14.00 | - | 3.00 | - | - | 37.25 |
| Carawy seeds | - | 1.00 | 1.25 | - | - | - | - | 2.25 |
| Total Area | 793.83 | 2,634.37 | 7,000.18 | 4,256.16 | 3,145.45 | 1,400.50 | 10.00 | 19,240.5* |

* Includes 7,794 feddans unofficially irrigated, of which 1,137.25 are in West Qasr El-Farafra

*APPENDIX B*

**WATER USER UNIONS IN EL-FARAFRA OASIS**

**Documents of Membership, Land Holding, and Registration 9.**

**10.**

**Copies of the Official WUU Certificates from the MPWWR NVWRDD As Provided 11. for Under Law 213**

# APPENDIX B

## WATER USER UNIONS IN
## EL-FARAFRA OASIS

**Documents of Membership, Land Holding,**
**and Registration**

**WUU Operational By-Laws**

**Copies of the Official WUU Certificates**
**from the MPWWR NVWRDD**
**As Provided for Under Law 213**

*APPENDIX C*

## EL-FARAFRA FOCUS WORKSHOP SUMMARY

**January 1999 12.**

# APPENDIX C

# EL-FARAFRA FOCUS WORKSHOP SUMMARY

**January 1999**